San Francisco–Oakland Bay Bridge
East Span Seismic Safety Project

FINAL SFOBB Pier E3 Implosion Demonstration Project Report

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Caltrans

Acknowledgments

The California Department of Transportation (Department) would like to acknowledge its agency partners for their contribution to the success of the Pier E3 Demonstration Project. The following agencies provided invaluable input, direction and support to the project and allowed the Department to design and implement this innovative and environmentally-responsible method of removal of the largest marine foundation of the original San Francisco-Oakland Bay Bridge East Spans:

San Francisco Bay Conservation and Development Commission

United States Army Corps of Engineers

National Oceanic and Atmospheric Administration – National Marine Fisheries Service

California Department of Fish and Wildlife

San Francisco Bay Regional Water Quality Control Board

United States Fish and Wildlife Service

United States Coast Guard

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List of Abbreviated Terms

°F	degrees Fahrenheit
μPa	microPascal
ADD	acoustic deterrent device
AMA	Aimone-Martin Associates LLC
BA	Biological Assessment
BART	Bay Area Rapid Transit
BAS	Blast Attenuation System
Bay	San Francisco Bay
BMP	best management practice
BO	Biological Opinion
CDB	Contract Drilling & Blasting LLC
CDFW	California Department of Fish and Wildlife
CESA	California Endangered Species Act
CFGC	California Fish and Game Commission
CFIMIS	Caged Fish Immediate Mortality and Injury Study (Caged Fish Study)
CHP	California Highway Patrol
CL	centerline
cSEL	Cumulative Sound Exposure Level
CTD	conductivity-temperature-depth
d	bubble curtain width
dB	decibel(s)
dBA	A-weighted decibel(s)
D_{cl}	BAS centerline
Delta	Sacramento–San Joaquin Delta
Demonstration Project	Demonstration project to remove Pier E3 as part of the San Francisco–Oakland Bay Bridge East Span Seismic Safety Project
Department	California Department of Transportation
DO	dissolved oxygen
DPS	Distinct Population Segment
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ESA	environmentally sensitive area
FEIS	Final Environmental Impact Statement
FESA	Federal Endangered Species Act

FFT	Fast Fourier Transform
FHWA	Federal Highway Administration
FHWG	Fisheries Hydroacoustic Working Group
FMP	Fishery Management Plan
GI	gastro-intestinal
GPS	global positioning system
HFII	High-Frequency Cetaceans
Hz	hertz
IHA	Incidental Harassment Authorization
in/s	inch per second
ITP	Incidental Take Permit
kHz	kilohertz
LFII	Low-Frequency Cetaceans
Lpk	highest peak pressure level
MBTA	Migratory Bird Treaty Act
MFII	Mid-Frequency Cetaceans
MLML	Moss Landing Marine Laboratory
mm	millimeter(s)
MMEZ	Marine Mammal Exclusion Zone
MMO	marine mammal observer
MMPA	Marine Mammal Protection Act
ms	millisecond
MSA	Magnuson-Stevens Fishery Conservation and Management Act (Sustainable Fisheries Act)
MTSZ	Marine Traffic Safety Zone
NEPA	National Environmental Policy Act
NGVD	National Geodetic Vertical Datum
NMEA	National Marine Electronics Association
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NTU	nephelometric turbidity units
OTD	Oakland Touchdown
OWI	Otariidaes
PCC	Portland cement concrete
P_{pk}	peak pressure in pounds per square inch
project	SFOBB East Span Seismic Safety Project
psi	pounds per square inch

psi-ms	psi-milliseconds
PTS	permanent threshold shift
PWI	Phocidaes
RMS	Root Mean Square
RTA	real-time analyzer
SAP	sampling and analysis plan
SEL	Sound Exposure Level
SFOBB	San Francisco–Oakland Bay Bridge
SMP	self-monitoring program
S/s	samples per second
TS	target strength
TTS	temporary threshold-hearing shifts
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
V	Volt(s)
WQS	Water Quality Study
WSDOT	Washington Department of Transportation
YBI	Yerba Buena Island

Chapter 1. Introduction

1.1. Background

The California Department of Transportation (Department), as part of the San Francisco–Oakland Bay Bridge (SFOBB) East Span Seismic Safety Project (SFOBB Project), is in the process of dismantling the original east span of the SFOBB. As part of the dismantling phase of the SFOBB Project, the Department completed a demonstration project to remove Pier E3 via highly controlled charges (Demonstration Project). Controlled implosion was expected to result in fewer in-water work days, have a reduced impact on aquatic resources of San Francisco Bay (Bay), and require a shorter time frame for completion. For these reasons it was proposed as an alternate method to the original permitted mechanical methods for dismantling Pier E3. To minimize impacts on biological resources and determine the level of hydroacoustic noise from the Demonstration Project, the Department implemented several monitoring efforts. The purpose of this document is to provide a concise summary of the biological monitoring programs and the results from the Demonstration Project.

A draft version of the report was distributed to the Department's partnering agencies in January 2016 for review. Questions and comments were submitted by various agencies and the Department's responses were incorporated, as applicable, in this final version. All comments from the regulatory agencies and the Department's response to comments are included in the Response to Comments matrix, attached to this report as Appendix A. Significant content changes within this report will be underlined or strikethrough for ease of reviewing.

1.2. Purpose and Need

The purpose and need of this portion of the SFOBB Project is to remove fill in the waters of the Bay associated with the structural foundations of the original east span to fulfill environmental commitments of the project. The purpose of this report is to document data from the Pier E3 Foundation Implosion Demonstration Project (Demonstration Project). If the Demonstration Project is judged to have been successful in minimizing the impacts on the Bay environment during construction, the project team is expected to request authorization from permitting agencies to continue to use multiple small sequenced charges to remove other foundations of the original east span.

The need for the removal of the in-water foundations is based on the requirement to remove those foundations from the waters of the Bay as presented in the project Environmental Impact Statement (EIS) and project permits, which are fundamentally based on three factors: risk to marine navigation, environmental values to minimize fill in the bay and minimize disruption to natural water flow. The need to consider using sequenced explosives is based on the requirement to minimize impacts on the bay environment during deconstruction.

Chapter 2. Project Description

As part of the SFOBB Project, the Department replaced the east span of the SFOBB with a new bridge north of the original east span (Figure 1). The Department requested and received regulatory agency approvals and authorizations from the United States Army Corps of Engineers (USACE), the United States Fish and Wildlife Service (USFWS), the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS), the California Department of Fish and Wildlife (CDFW), the San Francisco Regional Water Quality Control Board (RWQCB), and the San Francisco Bay Conservation and Development Commission (BCDC) for the use of controlled charges to dismantle the Pier E3 marine foundation of the original SFOBB east span.

Figure 1. SFOBB Project Map

The project area is located in the central bay, between Yerba Buena Island (YBI) and the City of Oakland. The western limit of the project is the east portal of the YBI tunnel located in the City of San Francisco. The eastern limit of the project is approximately 1,312 feet (400 meters) west of the Bay Bridge toll plaza in the City of Oakland.

Construction of the original east span connecting YBI and the Oakland shoreline was completed in 1936. The original east span consisted of a double-deck structure 12,127 feet (3,696 meters) in length and approximately 58 feet (18 meters) wide, carrying five traffic lanes in both east-and westbound directions. The original structure is supported by 21 in-water bridge piers (Piers E2 through E22), as well as land-based bridge piers and bents on both YBI and Oakland. As shown in Figure 2, the original east span is divided into three major sections.

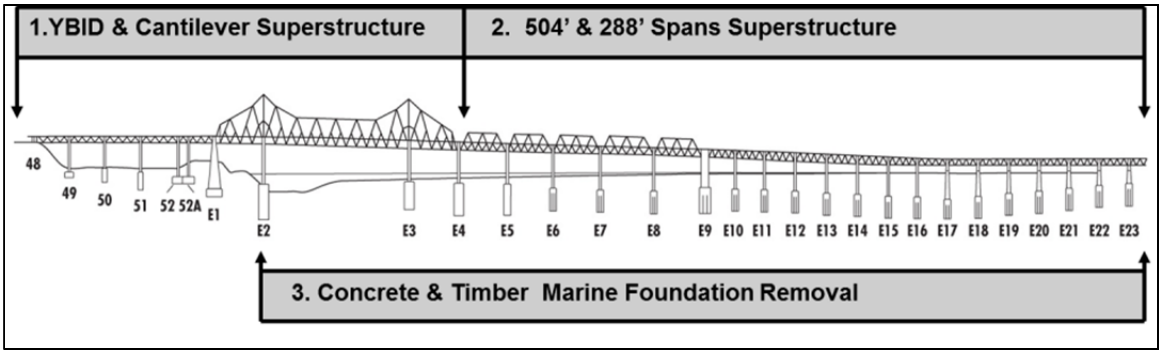


Figure 2. Elevation View Schematic of the Original SFOBB East Span

2.1. Cantilever Superstructure and YBI Detour

The cantilever section was comprised of three major components: (1) a 508 feet (154.8 meters) long cantilever anchor arm (2) a 512 feet (156 meters) long cantilever section; and (3) a 1,400 foot (426.7 meter) long main span over the navigation channel consisting of a suspended segment supported on either side by anchor arms. The superstructure of this segment included the trusses, road deck and steel support towers.

To complete construction of the new SFOBB east span and tie into the YBI tunnel, a portion of the original east span between Pier E1 and the YBI tunnel was dismantled in 2009 and replaced with the YBI Detour. The YBI Detour consisted of a double-decked bypass structure that connects into the original east span at Pier E1 on the east side of YBI.

2.2. 504-foot and 288-foot (504/288) Spans Superstructure

The 504/288 segment of the bridge is comprised of five 504-foot (153.6 meter) long steel truss spans and fourteen 288-foot (87.8 meter) long steel truss spans. The vertical clearance beneath the 504’ spans is approximately 165 feet (50 meters) above mean high water levels, while the vertical clearance beneath the 288’ spans gradually decrease from approximately 165 feet (50 meters) to approximately 10 feet (3 meters) as the structure descends towards the Oakland shoreline. The superstructure of this segment includes the trusses, road deck and steel and/or concrete support towers.

2.3. Marine Foundations

The in-water or marine foundations vary in type. Pier E2 is a cellular spread footing while Piers E3 through E5 consist of concrete caissons. Piers E6 through E22 consist of lightly reinforced concrete foundations that are supported by timber piles.

2.4. Dismantling of the SFOBB Original East Span

Dismantling of the SFOBB original east span began in late 2013. The dismantling was divided into multiple contracts corresponding to the different sections of the original east span (Figure 3). These contracts include:

- Demolition of the YBI Detour and Cantilever Structures (Yerba Buena Island Transition Structures [YBITS] 2 dismantling contract)
- 504/288 Contract
- Marine Foundation Contract

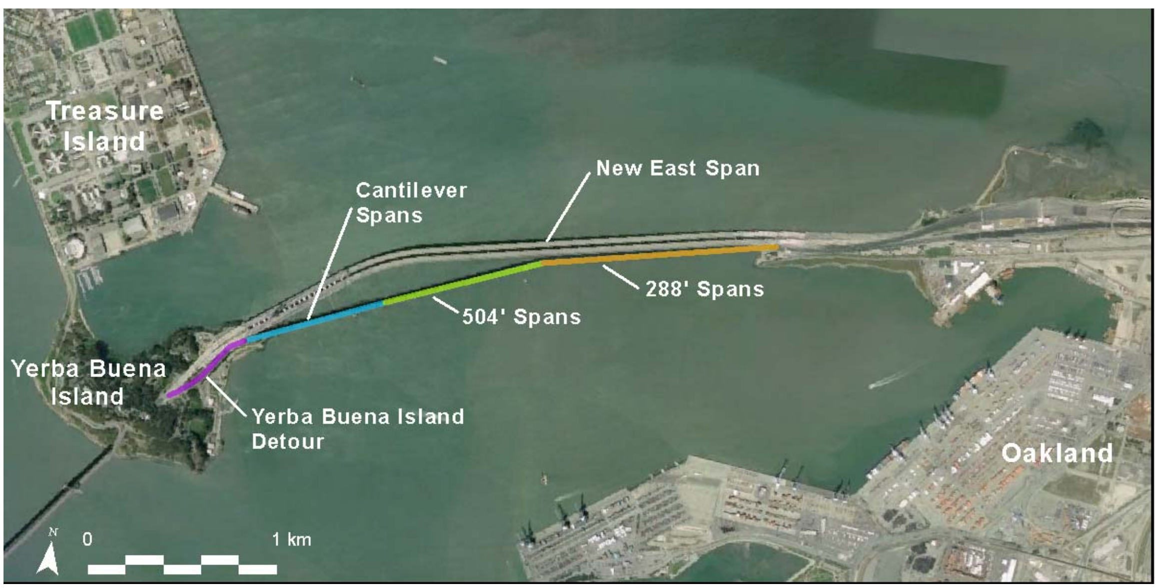


Figure 3. Sections of the Original SFOBB East Span

The first of the above-mentioned contracts, the YBITS 2 dismantling contract, started in late 2013 and includes the dismantling of the YBI Detour and Cantilever Structures. The second contract, the 504/288 dismantling contract, began work in mid-2015 and includes removing the superstructure and tower legs. Lastly, the marine foundation contract to remove Pier E3 was executed in April 2015. As the first marine foundation available for dismantling and the largest, Pier E3 was selected to demonstrate the effective use of controlled charges in-water to remove the marine foundations.

The original regulatory agency authorizations for the project covered the dismantling of the original east span via mechanical methods. In 2012, the Department amended the project’s existing permits and received authorizations to build temporary trestles and falsework to facilitate the dismantling of the original east span. These approvals did not include the use of controlled implosion. For this reason, the Department sought approval for the use of controlled charges to dismantle the Pier E3 marine foundation.

2.5. FEIS Project Description Update and FEIS Re-Validation

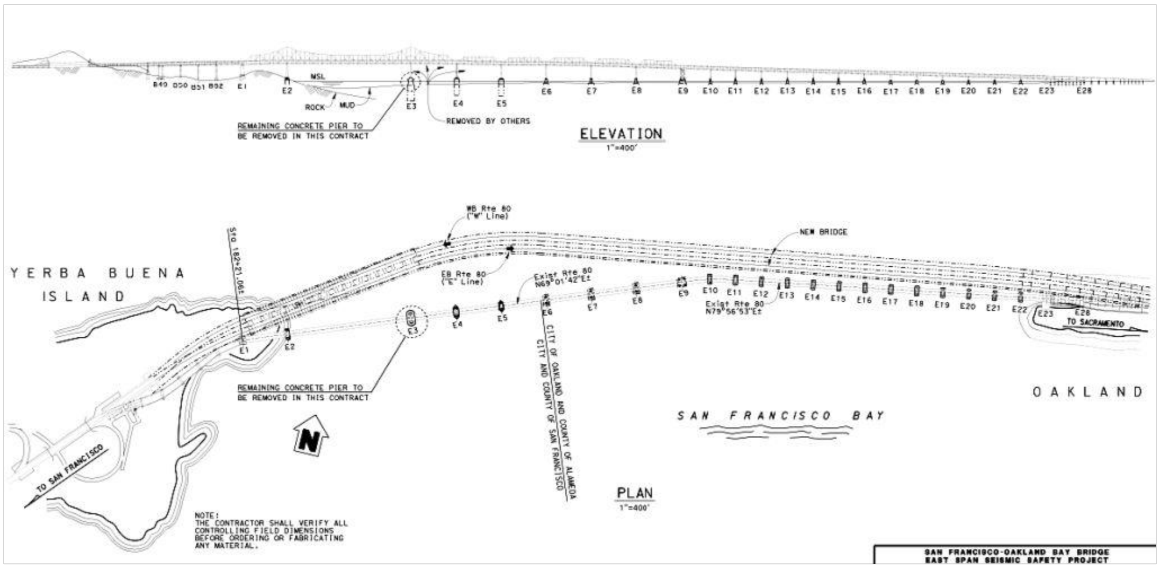
To address potential impacts on environmental resources during bridge construction and dismantling, the Department and the Federal Highway Administration (FHWA) completed the SFOBB Project Final Environmental Impact Statement (FEIS), in May 2001, pursuant to the National Environmental Policy Act (NEPA). In the same year, the Department also obtained approvals from regulatory agencies for all activities associated with both the construction of the new east span and the dismantling of the original east span. Mechanical dismantling methods and dismantling dredging were included in the FEIS and agency approvals. In addition, the FEIS and certain agency approvals contain language approving the disposal of all inert, non-toxic, and non-hazardous dismantling debris of the original bridge in the hollow pier footings.

To remove the marine foundations in an expedient manner with less environmental impact, the Department updated the original project description dismantling methods to include the use of controlled charges to remove the Pier E3 marine foundation. Based on the proposed modifications to the project description, the Department conducted a re-evaluation of the FEIS. The Department prepared a number of technical documents and based on these documents, the re-evaluation concluded that the use of controlled charges to remove the pier foundation would not result in new significant environmental impacts.

2.6. Pier E3 Site Location and Description

Pier E3 was located on the alignment of the original east span, 1,535 feet (468 meters) east of YBI near the coordinates 37^{0}48’56.75”N 122^{0}21’14.75”W, in San Francisco County (Figure 4). Pier E3 was located in an approximately 50-foot (15 meters) deep area of the Bay and flanked the east side of a deeper shipping channel.

The Pier E3 caisson was a cellular concrete structure approximately 268 feet (82 meters) tall containing 28 total chambers. Of these, there were 24 rectangular chambers and 4 irregular shaped chambers. Fourteen of the chambers occurred only below an elevation of approximately -51 feet (referenced to the 1929 National Geodetic Vertical Datum



Note:
Figure shows a schematic of the east span of the SFOBB showing the cantilever truss span and the former location of Pier E3 (circled) relative to other piers on the bridge.

Figure 4. Schematic of the East Span of the SFOBB

[NGVD 29]). These lower chambers were found in two separate rows of seven chambers on each length side of the structure. The four irregular shaped chambers occurred at the terminal ends of these lower chamber rows. Fourteen of the chambers ran lengthwise in two adjacent rows of seven through the middle of the structure and extend above the mudline to support the pier cap and concrete pedestals. The structure had 12 angled buttress walls that were approximately 51 feet (15.5 meters) tall. Six buttress walls were on each of the two lengthwise faces of the upper portion of the pier between -51 feet and 0 feet and were completely submerged at most times. All buttress walls were perpendicular to the structure. The hypotenuse side of each buttress wall ran at an angle from the outer top of the lower walls and terminated at the face of the structure (Figure 5). Weep holes in the foundation located at an approximate elevation of -5 feet allowed these chambers to fill with water. The water line inside the caisson varied with the tide, but +1.5 feet was the most common elevation measured in a Department sampling study of the caisson cell water before dismantling. Its cutting edge (deepest part of the caisson) remains at -231 feet (Figure 5). Approximately 175 feet (53 meters) of the structure's height remains buried in bay mud. The Pier E3 caisson does not reach bedrock.

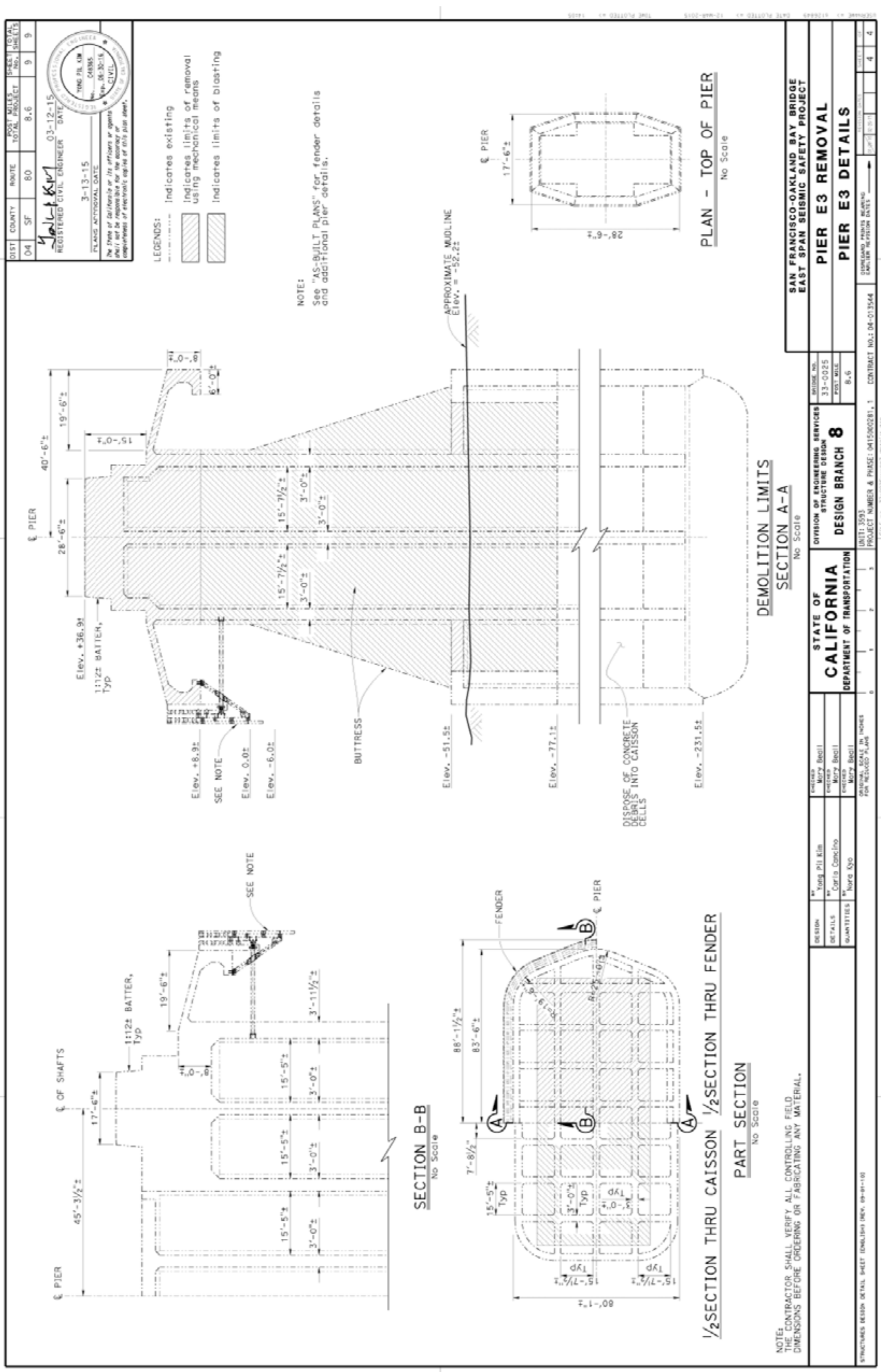


Figure 5. Final Plan Sheet of Pier E3 Showing Elevations, Dimensions, and Limits of Removal

Top dimensions of the pier cap were 40 feet (12.2 meters) by 134.5 feet (41 meters), not including the fender apron (Figure 5). Exterior walls along the perimeter of the caisson were 4 feet (1.2 meters) wide, while the interior walls comprising the rectangular chambers were 3 feet (1 meter) in width. The scoured mudline (i.e., the Bay floor) around Pier E3 ranges in elevation from -43 to -51 feet. The pier cap, fender system and upper most portions extended above the water line to support the steel superstructure of the cantilever section and were visible from the Bay (Figure 6).

Note:
View showing the wood structure and concrete apron of the fender system. The pier cap including the concrete pedestals are visible below the netted tower legs.

Figure 6. View of Pier E3 Facing Northwest

2.7. Pier E3 Demonstration Project Overview

On November 14, 2015, the Department removed Pier E3 by use of controlled charges and imploded the pier into its open cellular chambers below mudline. A Blast Attenuation System (BAS) was used to minimize impacts on biological resources in the Bay. The Department’s goal was to achieve a safe and efficient method for removing submerged foundations while avoiding and minimizing impacts on environmental resources in the Bay.

The Demonstration Project resulted in reduced environmental impacts as compared to permitted conventional dismantling methods which would require large cofferdams with extensive amounts of associated pile driving, and dewatering. The use of controlled charges has greatly reduced in-water work periods and shortened the overall duration of marine foundation removal for Pier E3.

2.7.1. Dismantling of Pier E3 Overview

Dismantling of Pier E3 took place in 4 phases:

- Dismantling of pier cap and fender system
- Drilling of bore holes into caisson and buttress walls and installing the BAS
- Installing charges, activating the BAS and imploding the pier
- Management and removal of remaining dismantling debris

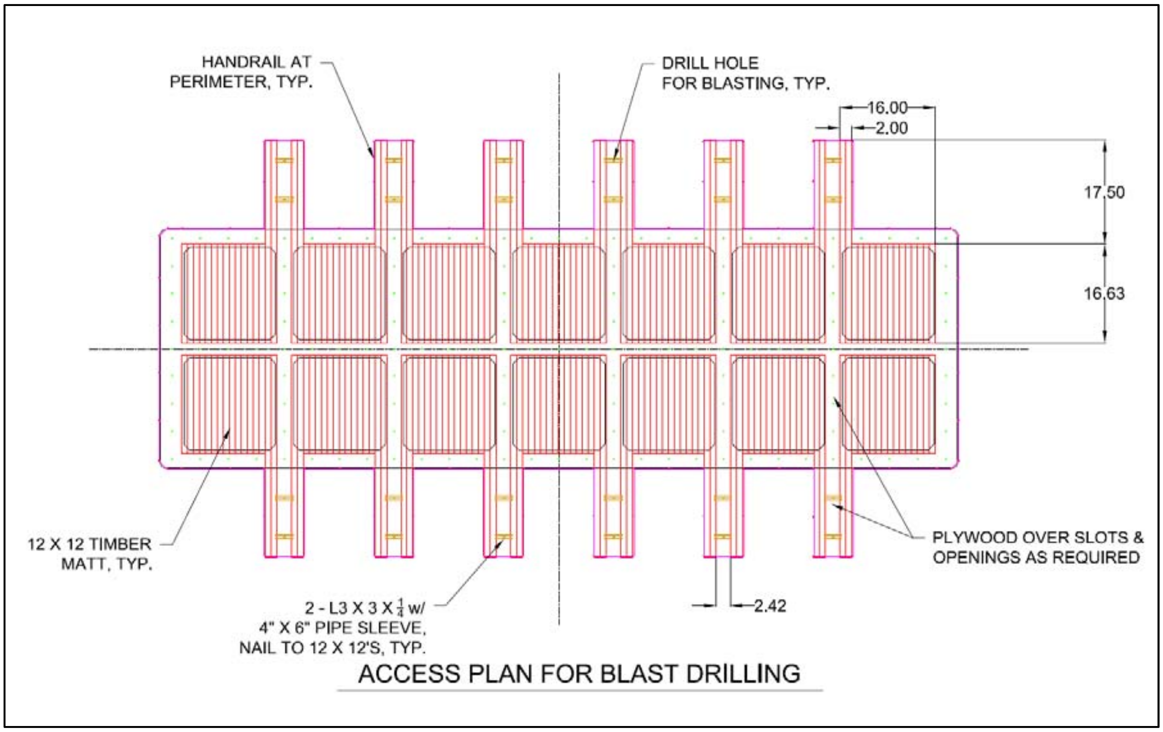
Dismantling of Pier E3 commenced in June of 2015, following the removal of the cantilever truss section and steel support tower that are part of the YBITS 2 dismantling contract. The basic steps involved were mechanically removing the timber and steel supported fender system that surrounded Pier E3, dismantling the concrete pier cap by mechanical means to an elevation of +9 feet, and drilling vertical boreholes where controlled charges were loaded for the controlled implosion per a project-specific blast plan (Blast Plan). Charges were loaded into the drilled boreholes as defined in the Blast Plan. Controlled implosion was then accomplished using hundreds of small charges with delays between individual charges. The entire detonation sequence of controlled implosion lasted approximately 5.3 seconds and removed nearly all of the pier to, or below, the current surrounding low scour elevation of -51 feet. The Blast Plan is include in Appendix Y.

2.7.2. Dismantling of Pier E3 Cap and Fender System

Dismantling of the Pier E3 cap started in June 2015. Support barges were used to move hydraulic excavators (equipped with hoe rams and shearing attachments and other equipment needed for dismantling), cutting lances and torches to Pier E3. A barge-mounted crane was used to move equipment onto and off of Pier E3. The fender system, including timber, metal framing, and concrete apron, was removed and disposed of off-site. The concrete pedestals, pier cap, and fender system were removed mechanically. Support platforms were installed to provide a working surface for the excavators to dismantle the upper portion of Pier E3. A debris containment system was in place to deter concrete debris from discharging into the Bay during dismantling operations. All concrete rubble from the mechanical dismantling was placed into exposed cells of the caisson and fell below mudline for disposal. The Department monitored for nesting birds, marine mammals, and water quality during mechanical dismantling and employed best management practices (BMPs) to prevent discharges into the Bay.

2.7.3. Drill Boreholes, Install BAS, and Controlled Implosion

After the pier was dismantled to the mechanical dismantling elevation, access platforms were installed to support the drilling equipment while exposing the top of the interior cells and outside walls (Figure 7). An overhanging template system was installed to guide the drill below the waterline. Divers were required to cut notches into the buttress walls to guide the drilling of underwater boreholes. A concrete drill rig drilled holes consistent with the Blast Plan.



Note:
This plan view shows installed platforms over all inner cells to support drilling equipment and installed overhang template system to facilitate drilling activities below the waterline.

Figure 7. Pier E3 Drilling Template Schematic

2.7.4. Controlled Implosion of Remaining Pier

The controlled implosion event took place on November 14, 2015, at 7:17 AM. Prior to the event, the bore holes in Pier E3 were loaded with controlled charges, as described in the Blast Plan. Individual cartridge charges, versus pump-able liquid blasting agents, were chosen to provide greater control and accuracy in estimating the individual and total charge weights.

Boreholes varied in diameter and depth and were designed to provide optimal efficiency in transferring the energy created by the controlled charges to dismantle the pier. Individual charge weights ranged from 21 to 35 pounds and total charge weight was 16, 875 pounds. Charges were arranged in different levels (decks) and separated in the boreholes by stemming. Stemming is the insertion of inert materials, such as sand or gravel, to insulate and retain charges in an enclosed space. Stemming allows for more efficient transfer of energy into the structural concrete for fracture, and further reduces the release of potential energy into the adjacent water column. The total number of charges and delays, and total shot time are provided in the Blast Plan.

Public safety measures were implemented during the controlled implosion event. Safety zones were established and enforced in conjunction with the California Highway Patrol (CHP) and CDFW to exclude marine traffic not directly involved in the implosion. Safety procedures, including a rolling traffic stop in both directions on the new east span of the SFOBB in advance of detonation, were implemented successfully.

2.7.5. Debris Removal and Site Restoration

Following the controlled implosion event and confirmation that the area was safe to work in, construction crews removed all associated equipment including barges, compressors, BAS, and blast mats. The greater majority of the Pier was successfully removed to the proposed removal limits. A small portion, including approximately 6 of the low corners of the buttress walls, remained approximately 3 to 6 feet above the -51 feet removal limit. These areas were removed mechanically.

Rubble resulting from the controlled implosion dismantling consisted of concrete and rebar. Most rubble fell within the caisson cells below mudline. Approximately 2,200 cubic yards (13 percent of the total rubble, including the removal of the pier cap) of rubble mounded on top of the caisson, or fell onto the bay floor next to the caisson. Rubble that did not fall into caisson cells was picked up and entombed within the caisson cells below mudline. Management of extraneous rubble was done by a barge-mounted crane with a clamming bucket. Buckets used during this debris management phase were equipped with a GPS unit to accurately guide the location of the bucket in the water. The clamming and in-water site management operation was completed on December 11, 2015.

2.8. Geotechnical

Geologic conditions are very poor from a structural and geotechnical perspective along the entire bridge between piers E3 and E22. The bay floor soil at the piers consists of young bay mud and is extremely soft and weak. This condition is the major reason the foundations of the new bridge extending down 300 feet. This is relevant to the foundation removal work because the poor soil conditions would require long, large and many piles for both strength and stability for any structure such as cofferdams constructed along the alignment. Figure 8 shows the subsurface soil conditions along the original bridge alignment.

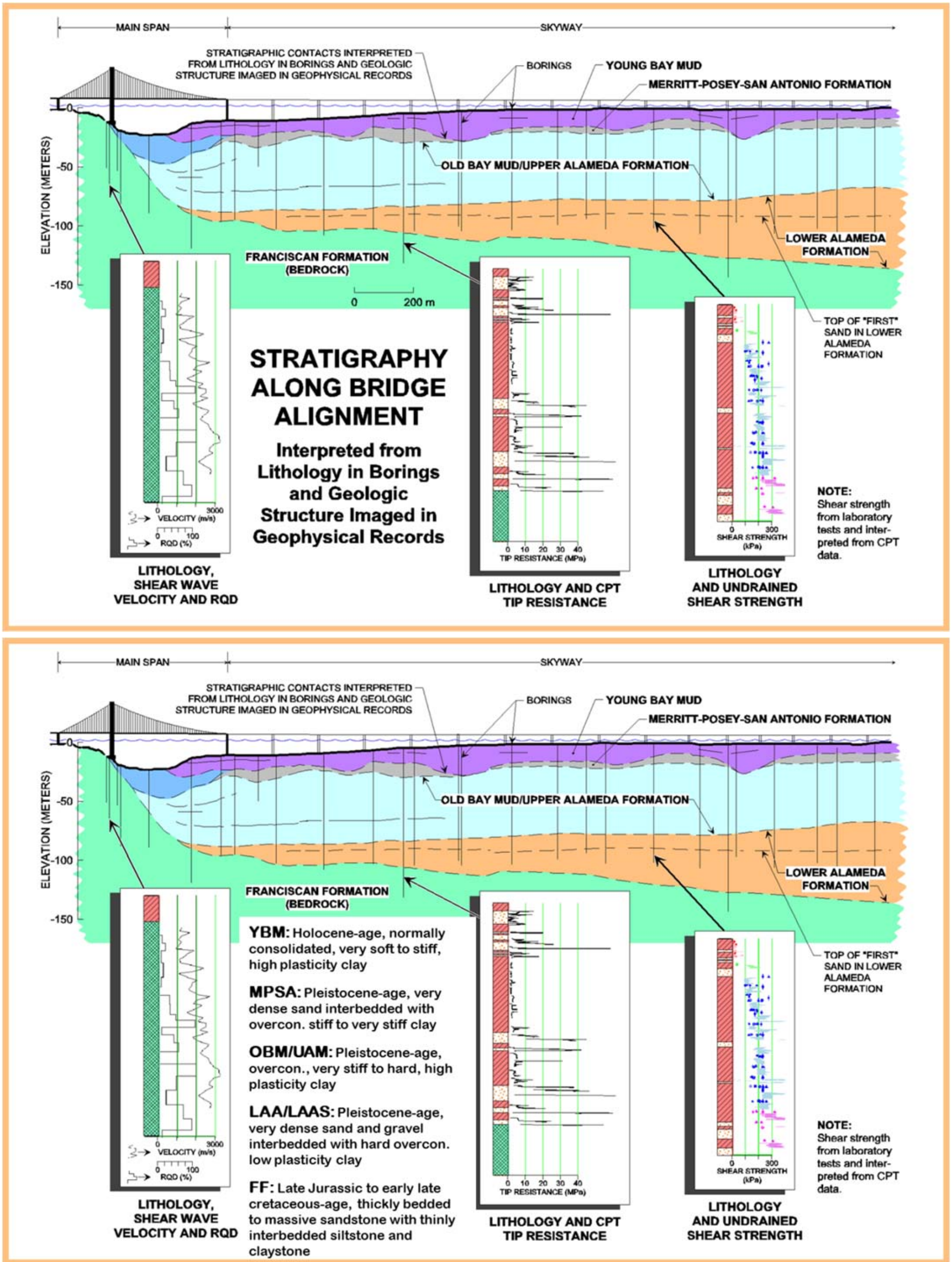


Figure 8. Soil Profile along the Alignment of the Original Bay Bridge East Spans

Chapter 3. Environmental Setting

3.1. Physical Conditions

3.1.1. Climate and Topography

The San Francisco Bay is the largest estuary along the western coast of the United States and is characterized by a Mediterranean climate. Generally, the climate is defined as having a dry season in the summer and fall followed by a wet winter. However, a variety of features ranging from coastal mountain ranges, inland valleys, and smaller bays within the larger Bay create unique local climates. Coastal areas are typically cooler than inland areas, and northern portions of the Bay generally receive more rainfall than southern areas. Average high temperature in San Francisco is 63.7 degrees Fahrenheit (°F), and average low temperature is 51.1°F.

3.1.2. Hydrology

The project area is located within the San Francisco Bay hydrological region. Fresh water from the Sacramento and San Joaquin Rivers enter the Bay at the Sacramento–San Joaquin Delta (Delta) before being carried into the Pacific Ocean through other portions of the Bay. Outflow from these rivers varies seasonally with rainfall and with releases of managed reservoirs and diversions located upstream.

Generally, freshwater outflow into the Delta (and into the Bay) is greatest during the spring and lowest in the late summer and fall. Furthermore, this interaction between freshwater outflow from the Delta and tidal conditions influence the salinity gradient in the larger Bay. In turn, numerous fish and wildlife species change their spatial distribution in the Bay in response to changes in this salinity gradient.

The project area is located in what is generally considered the Central Bay. The Central Bay is the deepest basin, is most influenced by the ocean, and has the saltiest water (on average) in the Bay. The deepest point is over 100 meters deep near the Golden Gate Bridge. The Central Bay has the most marine species in the Bay and likely the highest species diversity. Silting in of Remaining Pier E3 Structure

The remaining caisson cells below mudline are expected to silt in after the removal of the Pier E3. The Pier E3 site is located east of YBI in the Central Bay portion of the Bay in a deep-water area, approximately 40 to 55 feet (12 to 16.75 meters) deep, flanking the east edge of a deeper channel that runs generally north-south. The sandy sediments in this portion of the Bay are understood to be sourced from shoreline sediments from outside the Bay, or from the Sierras via San Pablo Bay. Sediments in the Central Bay are estimated to be up to 100 meters thick. The deep channel area around Pier E3 is also subject to strong tidal currents of up to two knots. The Department estimates that the area to be filled in with sediment after completion of the Demonstration Project is approximately 22,190 cubic yards (16,965 cubic meters) (Table 1). Now that the majority of the sediment loads introduced by hydraulic mining and during the 19th century California gold rush and agricultural practices of that era have flushed through watersheds and the Bay, current trends show a reduced annual sediment input into the Bay. However sediment input still remains on the order of over 5 billion pounds (2.3 million metric tons) annually (Bernard et al. 2013; BCDC 2014). Given this large annual input, the relatively small volume of the pier area, the known strong tidal action and sediments already present in the Bay, the Department believes the silting in of the Pier E3 caisson will have less than a minimal impact on sediment transport in the Bay. Furthermore, the Department believes that given the relatively small area being exposed for silting in, the Pier E3 caisson remaining below mudline will likely fill within a few major storm cycles.

Table 1. Pier E3 disposal volume calculations

	Volume (Cubic Yards)	Volume (Cubic Meters)
Total Volume Available in Caisson Cells	38,295	29,280
Total Volume of Concrete to be Disposed In-situ	10,065	7,695
Total Volume of Concrete to be Disposed In-situ with 1.6 Bulking Factor*	16,105	12,310
Surplus Capacity to be Silted In	22,190	16,965

*To account for the volume expansion of concrete material after it has been pulverized, a standard estimated 1.6 bulking factor is applied to the total volume of source concrete volume.

The Department asserts that the measures proposed will fulfill current permit requirements for the removal of permanent fill in the Bay by dismantling Pier E3 to the low scour line and allow for opportunity to work with its resource agency partners to satisfy the needs of the Bay.

3.1.3. Substrate/Sediments

Most of the Bay within the vicinity of Pier E3 is comprised of small, soft particles that can be moved by tidal currents. Sediments range in size from clay (0.001 to 0.0039 millimeter [mm]) to silt (0.0039 to 0.0625 mm) to sand (0.0625 to 2 mm). Larger particles, including gravel (2 to 64 mm) and cobble (64 to 256 mm) also can be found in soft bottomed habitats. Sand deposits can be found through the deeper parts of the Central Bay and the main channel through San Pablo Bay. Strong tidal currents along the

Bay floor make it a dynamic environment, with significant alteration and movement of sediments over time.

3.2. Biological Conditions

3.2.1. Background

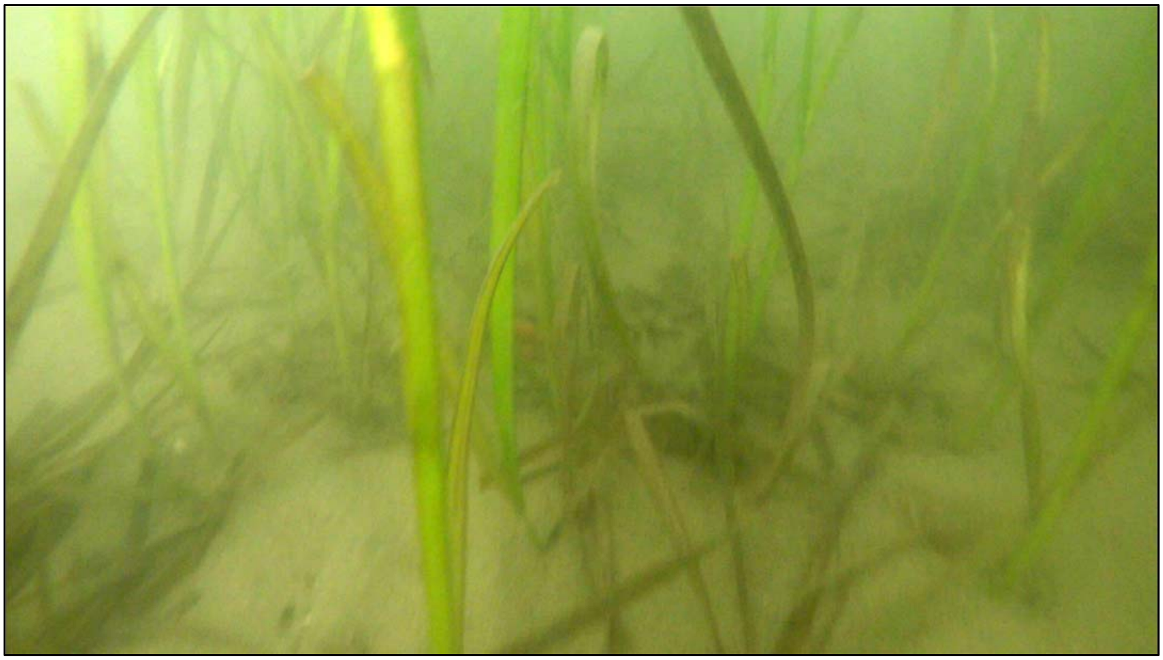
The open water environment around YBI and Treasure Island is almost entirely marine in composition because of a lack of significant freshwater flow. Numerous fish and marine mammals are known to occupy the Bay and are likely to occur, at some point in their life cycle, around Pier E3. In addition, many bird species are known to forage and nest throughout the original east span of the SFOBB, including on and around Pier E3.

3.2.2. Environmentally Sensitive Areas

The marine environment around Pier E3 consists of largely open water habitat along with subtidal and intertidal habitats closer to YBI and Treasure Island. Within intertidal zones, eelgrass (*Zostera marina*) beds occur along the northeast and east sides of Treasure Island and within Clipper Cove, adjacent to the northeast shore of YBI. In addition, historical records from 1999 and 2005 exist for eelgrass beds immediately off the southeastern shores of YBI. Eelgrass can also occupy the subtidal zone. Eelgrass is designated as an environmentally sensitive area (ESA) and is protected from encroachment from construction activities related to the implosion activities and the regular project activities.

Eelgrass meadows occur in shallow, saline regions of San Francisco Bay estuary (Figure 9). The major ecological roles of eelgrass include clearing water, trapping and stabilizing sediment, cycling nutrients, oxygenating water, and is a major base of a food web for invertebrates, fishes, and birds (Kitting 1994). This eelgrass food web can also extend to marine mammals. Eelgrass provides valuable shelter with concentrated food for juvenile and other small marine animals and as nursery areas for larger species including diverse economically valuable fisheries.

To protect and demarcate these ESAs, the Department installed buoys along their outer boundaries. To protect eelgrass beds during the Demonstration Project, all project-related equipment (e.g., barges, cranes, piles, BAS) were placed and/or staged outside the eelgrass ESA buoys. Extensive water quality monitoring was conducted before, during and after the implosion activities to assess impacts on the eelgrass beds as a result of the implosion. The monitoring methods and results related to water quality are included in subsequent sections of this report.



Note:
Photo taken during post-blast eelgrass distribution survey, at Emeryville Flats near Oakland Touchdown, November 23, 2015.
Source: Alluvion Biological Consulting (Caltrans 2015a)

Figure 9. View of an Eelgrass Bed

3.2.3. Federally/State Listed or Other Animal Species of Concern

3.2.3.1. FISH

Four federally and state listed fish species and their critical habitat are known to occur in the project vicinity. These species include Chinook salmon (*Oncorhynchus tshawytscha)*, steelhead (*Oncorhynchus mykiss*), longfin smelt (*Spirinchus thaleichthys*) and green sturgeon (*Acipenser medirostris*).

The Sacramento winter-run Chinook salmon is listed as endangered and the Central Valley spring-run Chinook salmon is listed as threatened under both the Federal Endangered Species Act (FESA) and California Endangered Species Act (CESA). Central Valley fall/late fall-run Chinook salmon is not listed. All Chinook salmon also are protected under the MSA. In addition, portions of the project area occur within EFH for several species managed under the MSA. The Central California Coast and Central Valley DPS of steelhead are listed as threatened under the FESA. The southern DPS of green sturgeon (*Acipenser medirostris*) was listed as federally threatened on April 6, 2006, by NMFS. This DPS of green sturgeon consists of all coastal and Central Valley populations south of the Eel River, with the only known spawning population in the Sacramento River (Federal Register 62:43937-43954). On October 9, 2009~~September 5, 2008~~, NMFS ~~issued a proposal that would~~ designated final critical habitat for green sturgeon (50 CFR Part 226, Federal Register, Vol. 74, No. 195). Designated critical habitat for this species includes the Bay Estuary. Longfin smelt are listed as threatened under the CESA and a managed species under the MSA (Caltrans 2015b).

3.2.3.2. Birds

The following protected bird species of concern are known to occur in the project area:

American Peregrine Falcon (*Falco peregrinus anatum*). Two pairs of peregrine falcons nest and roost on the SFOBB. One pair nests on the West Span and one pair on the East Span. Courtship behavior and other nesting activities can begin as early as December for these pairs. Eggs are usually laid in early March, and the young generally fledge in the third week of May. This species has been removed from federal listing, but is still protected by the Migratory Bird Treaty Act (MBTA) and the CESA.

Double-crested Cormorant (*Phalacrocorax auritus*). This species breeds in dense colonies that can be found on rocky coasts and offshore islands, as well as on inland lakes and rivers. Cormorants have the ability to nest at any time during the breeding season if the first nesting attempt is unsuccessful. Therefore, nests may be active any time between March and September. Double-crested cormorants have nested on the East Span of the SFOBB since 1984. The colony of double-crested cormorants includes 400 to 600 nesting pairs and represents the second-largest colony in Northern California. The highest concentrations of nesting pairs occur between Columns E5 and E15. The double-crested cormorant is designated as a species of special concern under the CESA.

California Brown Pelican (*Pelecanus occidentalis californicus*). The California brown pelican is known to rest on bridge footings and forage in the project area. No known nest sites occur in the project area. The California brown pelican is listed as endangered under both the State and Federal Endangered Species Acts.

Western Gull (*Larus occidentalis*). The western gull is protected under the Migratory Bird Treaty Act. Western gulls nest on the column footings of the SFOBB West Span and have the potential to nest on the footings of the East Span.

California Least Tern (*Sterna antillarum browni*). The California least tern nests in colonies on bare or sparsely vegetated areas near the coast. This species is found in the Bay Area during the breeding season from May through August. Nesting habitat which supports the California least tern does not occur within the study area. The California least tern is designated as an endangered species under both the State and Federal Endangered Species Acts.

3.2.3.3. MARINE MAMMALS

The following marine mammal species of concern are known to occur in the project area, though several are not common during the winter months:

Harbor Seal (*Phoca vitulina*). Harbor seals are protected from harassment under the federal Marine Mammal Protection Act (MMPA), as amended. Foraging sites are generally close to shore where medium-sized fish in addition to bivalves, crab, octopus, herring, and squid are taken as prey. Harbor seals use the south side of YBI as a haul-out site year-round. This site is located approximately 305 meters (1,000 feet) from the nearest construction limit boundary.

California Sea Lion (*Zalophus californianus*). Like the harbor seal, the California sea lion is protected by the Federal Marine Mammal Protection Act. While little information is available on the foraging patterns of California sea lions in the Bay, individual sea lions have been observed on a fairly regular basis in the shipping channel to the south of YBI. Individuals have also been sighted in the waters east of YBI. Pier 39 in San Francisco, about 4 miles (6 kilometers) from the project area, has become a haul-out site for sea lions. Most of the sea lions hauled out at this site are males and no pupping has been observed.

Northern Elephant Seal (*Mirounga angustirostris*). The northern elephant seal is protected under the MMPA, but it is not listed as a strategic or depleted species under the MMPA (Carretta et al. 2013), or listed as endangered or threatened under the FESA. The population size for the California breeding stock is estimated at 124,000 to 179,000 seals and is increasing (Lowry et al. 2010; Carretta et al. 2012). The elephant seal is not commonly seen in the Bay during the colder months.

Harbor Porpoise (*Phocoena phocoena*). The harbor porpoise is protected under the MMPA and is not considered a depleted or strategic stock under the MMPA (Carretta et al. 2012). Harbor porpoises are not listed as threatened or endangered under the Endangered Species Act. Census data suggest a stable population trend and the latest NMFS stock estimate for the San Francisco-Russian River stock is 9,189 porpoises. Harbor porpoise are not common in the area, however, an increasing trend of sightings has been observed over the last decade.

Chapter 4. Anticipated Impacts

4.1. Biological Resources

4.1.1. Fish

The Department submitted a Biological Assessment (BA) to NMFS to provide technical information about the proposed Demonstration Project and described potential effects to threatened, endangered, or proposed threatened or endangered species and their habitats on February 17, 2015. The BA was prepared in accordance with Section 7(a)(2) of the FESA (16 U.S.C. 1536[c]). The Department requested that NMFS re-open consultation and issue the Department a supplemental Biological Opinion (BO) and incidental take statement for potential impacts incidental to the Demonstration Project on NMFS-listed fisheries (Sacramento River winter-run Chinook salmon [endangered], Sacramento River spring-run Chinook salmon [threatened], , Central Valley steelhead DPS [threatened], Central California Coast steelhead DPS [threatened], Southern DPS of green sturgeon [threatened]), and critical habitat associated with NMFS-listed fisheries.

The BA also provided an analysis of potential adverse effects to Essential Fish Habitat (EFH)~~take~~ under the MSA~~, managed fisheries, and associated EFH. Eelgrass beds are classified as EFH~~. The entire Bay is classified as EFH for species managed under the Pacific Coast Salmon Fishery Management Plan (FMP; Coho and Chinook salmon) and also for species managed under the Coastal Pelagic Species FMP and Pacific Coast Groundfish FMP (Pacific Fishery Management Council 1998; 2005). Pelagic species that are not federally-listed but managed under the MSA include Pacific sardine, Northern anchovy, Pacific herring, jacksmelt, and English sole (*Parophrys vetulus*).

NMFS-jurisdictional fisheries include Endangered Species Act-listed species and MSA managed species. A summary of potential affects to NMFS-jurisdictional fisheries, associated critical habitat, and EFH is provided below.

- Based on analysis of the proposed Demonstration Project, NMFS ~~the Department~~ determined that the proposed project ~~would have no effect on Coho salmon,~~ may affect, but not likely to adversely affect Chinook salmon, or steelhead. NMFS ~~The Department concluded~~ determined that the proposed project would not jeopardize the continued existence of these species. Installation of a BAS and timing the implosion when these species are not present in the action area were proposed as methods by which to minimize ~~avoid~~ take to these species.

- NMFS determined the ~~The~~ proposed project had the potential to ~~was likely to affect, but not~~ adversely affect, green sturgeon. Installation of a BAS and timing the implosion when adults and sub-adults of this species are not present in the area were proposed as methods by which to minimize ~~avoid~~ take to these species. Juvenile green sturgeon, however, can occur anywhere in the Bay at any time of year. Although no data was available to inform this potential impact, the current understanding was that the potential for impact on juvenile green sturgeon was very low.

- The proposed project was expected to result in temporary impacts on critical habitat for Chinook salmon, steelhead, and green sturgeon through water quality impacts and high-intensity sound associated with the 4 to 6 second implosion. Temporary impacts on salmonid critical habitat were anticipated at the following totals:

  - 469.80 acres (190 hectares) for Central CA Coast steelhead and green sturgeon
  - 229.74 acres (93 hectares) for Central Valley steelhead and Chinook salmon

On June 12, 2008, the Fisheries Hydroacoustic Working Group (FHWG), whose members include NMFS's Southwest and Northwest Divisions, California, Washington, and Oregon Departments of Transportation, USFWS, CDFW, and FHWA issued an agreement for the establishment of interim threshold criteria to determine the effects of high-intensity sound on fish. ~~These criteria were established after extensive review of the most recent analysis of the effect of underwater noise on fish from pile driving in water.~~ The agreed-on threshold for the onset of injury to fish from sound pressure ~~criteria for noise to have an injury effect on fish~~ has been set at 206 decibel (dB) peak, 187 dB cumulative ~~accumulated~~ Sound Exposure Level (cSEL) for fish over 2 grams, and 183 dB cSEL for fish less than 2 grams (FHWG 2008). The FHWG has determined that sound pressure levels ~~noise~~ at or above these levels can cause injury to ~~damage to auditory tissues and temporary threshold-hearing shifts (TTS) in~~ fish. In addition, a threshold of 150 dB Root Mean Square (RMS) was established as the level that elicits a behavioral response, but no injury, in fish. A summary of effects to listed species and MSA managed fisheries is provided in Table 2 below.

Table 2. Predicted number of Listed Species and MSA species potentially affected by Pier E3 Implosion			
Species	**# of Individuals (206 dB peak Sound Pressure Level [SPL])**	**# of Individuals (187 dB cSEL)**	**# of Individuals (183 dB cSEL)**
Coho Salmon	0	0	Not Applicable (N/A)
Chinook salmon	0	0	N/A
Steelhead	0	0	N/A
Green Sturgeon	0	0	N/A
Northern Anchovy	18,938	160,825	197,513
Pacific Herring	246	1,641	N/A
Pacific Sardine	0	0	0
English Sole	2,568	24,455	24,993
Jacksmelt	381	2,594	3,080
Longfin Smelt	132	1,075	1,775

The anticipated impacts and minimization measures included the following:

- Installation of a BAS and implementation of BMPs were proposed as methods to limit the amount of temporary impacts on critical habitat. In addition, the removal of Pier E3 resulted in the permanent restoration of 16,995 cubic yards (12,990 cubic meters) of pelagic habitat.

- The proposed project was expected to result in temporary impacts to critical habitat for listed fish and ~~on~~ EFH through water quality impacts following pier implosion and during removal of debris, as well as, ~~and~~ high-intensity sound associated with the 4 to 6 second implosion. Temporary impacts were modeled to total approximately 1,026 acres (415 hectares).

- Impacts on eelgrass beds were not anticipated from the proposed project. Installation of a BAS and implementation of BMPs, including the monitoring of eelgrass were proposed as methods by which to limit the amount of temporary impacts on critical habitat.

- Physical disturbance or shading of eelgrass was not anticipated from the proposed project. Care, however, was taken to ensure project-related equipment (e.g., barges, cranes, piles, BAS) were not placed or stored in a manner to cause physical disturbance or shading of any eelgrass communities.

4.1.1.1. STATE PROTECTED FISH SPECIES

The Department requested a major amendment to its CDFW-issued Incidental Take Permit (ITP), pursuant to Section 783.6(c)(4) of the California Code of Regulations for potential impact incidental to the Demonstration Project on CDFW-listed fisheries (Sacramento River winter-run Chinook salmon (endangered), Sacramento River spring-run Chinook salmon (threatened), Central California Coast Coho salmon (endangered), longfin smelt (threatened)), CDFW-managed fisheries (Pacific herring), and habitat associated with CDFW-listed fisheries on February 18, 2015. A summary of potential affects to CDFW-jurisdictional fisheries is provided below.

- The proposed project was expected to have no effect to CDFW-listed Chinook salmon and Coho salmon. Installation of a BAS and timing the implosion in November when these species are not present in the area of impact were proposed as methods to avoid take of this species.

- The Demonstration Project had potential to result in effects to Pacific herring. However, these potential effects were estimated at 1,641 individual Pacific herring, which represented only 0.5 percent of the larger Central/South Bay population in November. Installation of a BAS, timing the blast when this species is at its lowest seasonal density, and conducting Pacific herring monitoring, if work were to be conducted during the spawning season, were proposed as methods by which to avoid effects to this species resulting from the Demonstration Project.

- The Demonstration Project had potential to result in take of longfin smelt. However, take was estimated at 1,775 individual longfin smelt, which represented only approximately 1.3 percent of the Central/South Bay population present in November. Installation of a BAS and timing the blast when this species is at a lower density in the area of impact were proposed as methods by which to avoid take of this species.

- The proposed project was expected to result in temporary impacts on longfin smelt and Pacific herring marine habitat through water quality impacts and high-intensity sound associated with the 4-6 second blast. Temporary impacts were estimated to total 1,026 acres (415 hectares). Installation of a BAS and implementation of BMPs were proposed as methods by which to limit the amount of temporary impacts on marine habitat.

4.1.2. Birds

With the exception of endangered avian species (e.g., marbled murrelets), there are no official in-air sound thresholds for evaluating the potential for auditory damage to birds from impulse noise events like pile-driving or implosions. Dooling and Popper (2007), in a white paper reviewing the effects of noise on avian behavior, suggested interim thresholds of 140 A-weighted decibel (dBA) for a single impulse event (e.g., detonation of a single charge) and 125 dBA for multiple impulse events (e.g., repeated charges or pile-driving strikes) See Table 3.

Table 3. Recommended Interim Guidelines for Potential Effects to Birds from In-air Sound Generated by a Single- or Multiple- Impulse Event (from Dooling and Popper 2007).

Noise Source Type	Hearing Damage	TTS	Masking	Potential Behavioral/ Physiological Effects
Single Impulse (e.g., blast)	140 dBA	NA	NA	Any audible component of highway noise has the potential of causing behavioral and/or physiological effects independent of any direct effects on the auditory system of PTS, TTS, or masking
Multiple Impulse (e.g., jackhammer, pile driver)	125 dBA	NA	ambient dBA	

The literature suggests that birds are most sensitive to sounds from around 1 to 4 kilohertz (kHz) (1,000 to 4,000 hertz [Hz]), but they can perceive sounds at higher or lower frequencies (Beason 2004). The recognized typical low-frequency cut-off of hearing in birds is between 250 to 300 Hz (Heffner & Heffner 1998; Dooling and Popper 2007). In contrast, humans have a hearing range from 20 Hz to 20 kHz and hear as well or better than birds over a wider range of sound frequencies (Dooling and Popper 2007).

Sound data provided to the Department by the blasting contractor from previous in-water implosion events document in-air sound levels that ranged from 146 dBA at 8 feet to 105 dBA at 340 feet from the underwater blasts. Fitting a best-fit line to these data, in-air sound levels drop below Dooling and Popper's interim guideline value of 125 dBA within 200 feet of the implosion. However, and more importantly, sound frequencies during these past implosions ranged from 2 to 23 Hz, which are well below the typical low-frequency cut-off value for most birds.

The Department concluded that in-air sound levels from the implosion are likely to fall below 125 dBA within 200 feet of the implosion and these loudest sources of noise occur at frequencies (2 to 23 Hz) that are not detected by birds. Therefore, the implosion is likely to have negligible in-air auditory effects to birds because of the low frequency signature of the noise.

4.1.2.1. IN-WATER NOISE REGULATORY THRESHOLDS AND ANALYSIS

To evaluate the potential for auditory damage to birds from impulse noise in-water, the Department used the 2014 USFWS and Washington Department of Transportation (WSDOT) criteria for injury to the marbled murrelet resulting from impact pile driving of steel piles. These threshold criteria were developed to evaluate the effects of impact pile driving on foraging marbled murrelets in the marine environment. This guidance established a 202 dB cSEL threshold for auditory injury and 208 dB cSEL for non-auditory injury from underwater noise, as well as a 150 dB RMS potential behavioral response zone. These thresholds are summarized in Table 4. USFWS considers the 150 dB RMS zone to be a guideline, not a threshold.

Table 4. Criteria for Injury to Marbled Murrelets from Underwater Sound Resulting from Impact Pile Driving (from WSDOT 2014).

Type of Injury	Threshold
Auditory Injury	202 dB cSEL
Non-auditory Injury	208 dB cSEL
Potential Behavioral Response	150 dB RMS

The Department used the 202dB cSEL criteria for auditory injury to assess the potential hydroacoustic impact on birds exposed to the in-water impulse sound generated by the implosion of Pier E3. The Department calculated a 500-foot distance to the 202 dB cSEL threshold.

Specific avoidance and minimization measures were developed to minimize impacts on birds that are likely to dive and/or forage in the water column around Pier E3 during the implosion. Of particular concern were diving birds protected by MBTA, FESA and CESA listed bird species, and California Fish and Game Code (CFGC) fully-protected bird species. The only diving FESA and CESA listed species that may occur in the vicinity of Pier E3 is the California least tern and the only CFGC fully protected species that are known to occur in the vicinity of Pier E3 is the California least tern and the California brown pelican. Specific avoidance and minimization measures include:

- The implosion was scheduled for November. During project-related bird monitoring conducted from 2002 to 2014, California least terns have only been observed during their April to August nesting season. Therefore, California least terns were not expected to be in the Demonstration Project area in November. Monitoring data also shows a reduced number of California brown pelican sightings in November.

- The Department implemented an avian monitoring plan to reduce the potential for project-related bird effects. This plan included the following avoidance and minimization measures:

  - Establishment of a 500-foot (152-meter) Avian Watch Zone around Pier E3 to protect diving birds.
  - Use of deterrents to encourage target avian species to relocate from the 500-foot Avian Watch Zone. Deterrents included the use of a high-powered laser and sound cannons.
  - The Department stationed avian monitors at two locations in the vicinity of Pier E3 to observe bird activity prior to, during, and following the implosion.
  - Per the avian monitoring plan, the implosion would be delayed if any USFWS or CDFW special-status birds (including California least tern or California brown pelican) were actively diving into the water within 500 feet of Pier E3 immediately prior to the implosion.

4.1.3. Marine Mammals

The Department requested an Incidental Harassment Authorization (IHA) from NMFS pursuant to Section 101(a)(5)(A) of the MMPA for the harassment of marine mammals incidental to the Demonstration Project. The Department determined that the following marine mammals could have been affected by the Demonstration Project: California sea lion, Pacific harbor seal, northern elephant seal, and harbor porpoise. A summary of potential impacts on marine mammals is provided next.

4.1.3.1. Impacts on Marine Mammal Habitat

The removal of Pier E3 through controlled implosion was determined to be unlikely to negatively affect the habitat of marine mammal populations, as no loss of habitat would occur and only a minor, temporary modification of habitat would occur from the hydroacoustic impacts of the controlled implosion. The SFOBB is not used as a haul-out site by pinnipeds, and dismantling of the concrete marine foundations is unlikely to permanently decrease fish populations, a primary food resource for many marine mammals. The physical effects from pressure waves generated by underwater impulse sounds (e.g., underwater implosions) were anticipated to affect fish populations within the proximity of project activities. The abundance and distribution of fish near Pier E3 could be altered for a few hours after the implosion and before individual fish from surrounding areas are redistributed within the area. These fish populations, however, were anticipated to return to pre-implosion levels as project activities cease and the local population mixes again.

4.1.3.2. IMPACTS ON MARINE MAMMAL POPULATION

The numbers presented in Table 5 represent estimated modeled exposures to each harassment threshold criteria zone under the MMPA. These calculated values were conservative (i.e., over predictive) estimates of harassment, that calculated exposure without taking into consideration avoidance and minimization measures that would be employed (i.e., marine mammal observers, real time acoustic monitoring). As a result of

Table 5. Summary of the estimated exposures of marine mammals to controlled blasting dismantling activities for each of the Level A, Level B, and mortality threshold criteria.

Species	LEVEL B EXPOSURES		LEVEL A EXPOSURES*			Mortality*
	Behavioral Response	Temporary Threshold Shift	Permanent Threshold Shift	Gastro Intestinal Tract Injury	Slight Lung Injury	
Pacific Harbor Seal	6	3	0	0	0	0
Northern Elephant Seal	1	0	0	0	0	0
California Sea Lion	0	0	0	0	0	0
Harbor Porpoise	1	0	0	0	0	0
Total	8	3	0	0	0	0

* No detonations would occur if any marine mammal was within Level A or mortality threshold criteria zones.

this analysis and through the implementation of these measures, the Department concluded that the controlled implosion of Pier E3 would only result in Level B Behavioral Harassment, or TTS. Level B Harassment is statutorily defined by the 1994 amendments to the MMPA as any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild (Public Law 103-238, April 30, 1994, 108 Statute 532). Based on the best available science, exposures to marine mammal species and stocks because the controlled implosion would result in only short-term effects to individuals exposed, would likely not affect annual rates of recruitment or survival, and employed avoidance and minimization measures will prevent any Level A exposures or mortality. Level A Harassment is statutorily defined by the 1994 amendments to the MMPA as, any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild (Public Law 103-238, April 30, 1994, 108 Statute 532).

Based on observations during 14 years of previous construction and dismantling activities associated with the SFOBB Project, the protective measures described, and the very short duration of the explosion, the Department anticipated there would be no permanent injury or mortality to animals, or impacts (short or long term) on the populations or stocks of marine mammals that regularly inhabit or occasionally enter the Bay.

4.2. Waters and Water Quality

As described below, the Demonstration Project was expected to have some impact on waters and water quality.

4.2.1. Impacts on Water Quality during Controlled Implosion

A Water Quality Study (WQS) was prepared by the Department and submitted to resource agencies (Caltrans, 2015c). The WQS examined potential water quality impacts caused by turbidity and suspended sediment, pH, non-visible pollutants, and temperature. The WQS demonstrated that potential impacts on water quality would be minimal and temporary, and that no permanent impacts on water quality were anticipated to result from the Demonstration Project.

Two additional technical reports evaluated the potential impacts from Portland Cement Concrete slurry created during the implosion and the potential impacts on sediment quality and benthic habitat from cement residue released from PCC during implosion. The first technical report provided a conservative estimate of increase in pH caused by an assumed release of alkalinity-changing materials (Table 6). The second technical report predicted a low potential for benthic impacts caused by the settling of fine concrete residue resulting from the controlled implosion of Pier E3.

Table 6. Predicted pH Effect under Two Scenarios (salinity. 32 parts per trillion).

Scenario	~100 foot distance	~1,000 foot distance	~2,000 foot distance
Explosives-only scenario	8.7	8.2	8.2
Explosives and dissolution of 5 percent of Pier E3 mass	12.7	11.3	9.1

Changes in pH were expected to be the most significant water quality impact. The pH would increase as a result of explosive by-products and the release of fine-grained PCC residue from the imploded structure. Two scenarios were modeled: pH impacts because of release of explosive by-products only, and pH effects from the release of explosive by-products along with dissolution of 5 percent of the mass of the Pier E3 as soluble calcium oxide from PCC (Table 6).

The pH was not expected to exceed 9 standard units within the affected area under the explosives-only scenario, and the effects would diminish within hours of implosion as a result of mixing from tidal currents. The more extreme effects predicted by release of calcium oxide from 5 percent of the total mass of the pier was deemed unlikely, based on the experience from the Port Mann Bridge demolition as well as the higher buffering capacity of San Francisco Bay water relative to the Fraser River (the river over which the Port Mann Bridge passes).

Turbidity was expected to be the next most significant water quality impact. The maximum turbidity was predicted by in the Department's Water Quality Study for the Pier E3 Demonstration Project (Caltrans 2015c) to be 300 nephelometric turbidity units (NTU), rapidly dropping to below 50 NTU within 50 minutes, and back to baseline within four hours. Changes in the water column temperature and concentrations of metal and dissolved oxygen (DO) were expected to be *de minimis*.

4.2.2. Impacts on Water Quality during Site Restoration

Site restoration included movement of concrete rubble into the void created by the implosion of Pier E3. During this phase, water quality impacts were anticipated to be minimal. To verify this, monitoring was conducted in accordance with methods and standards outlined in the Water Quality Self-Monitoring Program required by the RWQCB Order No. R2-2002-0011, or as required by the RWQCB (RWQCB 2002).

4.2.3. Fill

In the 2001 FEIS and original applications submitted to regulatory agencies, the Department acknowledged that the project would result in a net decrease to fill in the Bay after the installation of the new east span and removal of the original bridge. A volume of 85,600 cubic yards (65,450 cubic meters) of permanent fill was calculated from the piers and fenders of the original bridge. The dismantling of Pier E3 to low scour line represents the removal of approximately 16,995 cubic yards (12,990 cubic meters) of permanent fill in the Bay consisting of 15,745 cubic yards (12,035 cubic meters) of permanent fill from the concrete pier structure and approximately 1,250 cubic yards (955 cubic meters) of permanent fill removed via the pier fender system. This removal of permanent fill in the Bay restored approximately 16,995 cubic yards (12,990 cubic meters) of pelagic habitat.

Chapter 5. Environmental Monitoring Methods

5.1. Water Quality Monitoring

A water quality monitoring program was conducted to verify predictions of potential impacts as described in the WQS for the Demonstration Project (Caltrans 2015c). Water quality monitoring program activities are described in detail in the Demonstration Project sampling and analysis plan (Caltrans 2015d)

5.1.1. Implosion Monitoring Plan

To document impacts resulting from the controlled implosion, the SAP built on the self-monitoring program (SMP) contained in the project's Waste Discharge Requirement, Order No. R2-2002-0011 (2002). This SAP either met or exceeded the specifications provided in the SMP. Water quality monitoring for the controlled implosion consisted of five techniques:

- Dynamic Plume Mapping: Dynamic and static water column profiling techniques were used to define the three-dimensional extent of the plume and track its dispersion over a 5-hour window following the implosion. Dynamic profiling used a boat-towed monitoring array to continuous measure and defined the three-dimensional shape of the plume. Static profiling involved raising and lowering a monitoring device from a stationary vessel.

- Current-Tracking Drogues: Current drogues were used to track the movement of the plume and guide the profiling effort. Drogues were deployed in two sets – one set upstream of the plume and another downstream of the plume – to move with the current and track the plume in real-time. Attached buoys with GPS sensors and radio transmitters sent drogue position coordinates to the plume mapping vessel. A second vessel, the drogue tender, shepherded the drogues as they moved along with the current and prevented the drogues from encountering any obstructions.

- Environmentally Sensitive Area (ESA) monitoring: To confirm that the water quality in the vicinity of the eelgrass beds was not affected, five continuous monitoring buoys measured turbidity and pH at middle depth.

- Water Quality Grab Sampling: Water quality sampling was conducted from a third vessel. Grab samples were collected as the vessel moved along the path of the plume. Samples were measured for pH, turbidity and suspended solids concentration, and total and dissolved metals.

- Sediment Quality Assessment: Sediment analysis was conducted before and after the implosion to measure potential benthic effects. A random stratified sampling design was implemented to test the spatial variability of sediment chemistry (metals and pH) and toxicity at the sediment-water interface.

5.2. Hydroacoustic/Underwater Pressure Monitoring

5.2.1. Background: Regulatory Thresholds for Hydroacoustic Impacts

The criteria used by NMFS and CDFW to regulate for potential impacts on fish are those currently established by the FHWG for underwater impact pile driving along the U.S. West Coast (FHWG 2008). ~~These criteria were established after extensive review of the most recent analysis of the effect of underwater noise on fish from pile driving in water.~~ The criteria use two metrics, highest peak pressure level (L_{pk}) and ~~accumulated~~ cSEL. Peak pressure is the effective sound pressure level converted to dB of the highest monitored peak pressure measured at a single location during an underwater sound event. The cSEL is the total noise energy produced from a single noise event and includes both the intensity and duration of the pulses generated as monitored from a single point. The agreed-on threshold criteria for in-water noise for the onset of injury to fish has been set at a single-strike peak level (L_{pk}) of 206 dB referenced to 1 microPascal (re 1 µPa), 187 dB cSEL referenced to 1 µPa squared per second (re 1µPa2-s) for fish over 2 grams, and 183 dB cSEL re 1 µPa2-s for fish less than 2 grams (FHWG 2008). The FHWG determined that noise at or above these levels can cause injury to ~~damage to auditory tissues and TTS in~~ fish. In addition, a threshold of 150 dB RMS was used per the NMFS BO of August 2015 as the level that elicits a behavioral response, but no injury, in fish. ~~The 150 dB RMS threshold is reported at the request of regulatory agencies, but is not included as a criterion that is regulated.~~

Noise criteria for marine mammals used for the implosion of Pier E3 followed the interim underwater explosive criteria established by the National Oceanic and Atmospheric Administration (NOAA) and consist of cSEL, L_{pk}, and acoustic impulse. The cSEL criteria for marine mammals are complex as the levels vary by species and have individual frequency weightings that also vary by species. The marine mammal criteria are shown in Table 7.

Table 7. Marine Mammal Noise criteria and thresholds for underwater blasting

Group	Species	Behavior		Slight Injury			Mortality
		Behavioral (for ≥2 pulses/24 hours)	TTS	PTS	Gastro-Intestinal Tract	Lung	
Low-frequency Cetaceans	Mysticetes	167 dB SEL (LF_{II})	172 dB SEL (LF_{II}) or 224 dB peak SPL	187 dB SEL (LF_{II}) or 230 dB peak SPL			
Mid-frequency Cetaceans	Most delphinids, medium and large toothed whales	167 dB SEL (MF_{II})	172 dB SEL (MF_{II}) or 224 dB peak SPL	187 dB SEL (MF_{II})or 230 dB peak SPL			
High-frequency Cetaceans	Porpoises and *Kogia* spp.	141 dB SEL (HF_{II})	146 dB SEL (HF_{II}) or 195 dB peak SPL	161 dB SEL (HF_{II}) or 201 dB peak SPL	237 dB SPL or 104 psi	$39.1 M^{1/3} (1+[D_{Rm}/10.081])^{1/2}$ Pa-sec Where: M = mass of the animals in kg D_{Rm} = depth of the receiver (animal) in meters	$91.4 M^{1/3} (1+[D_{Rm}/10.081])^{1/2}$ Pa-sec Where: M = mass of the animals in kg D_{Rm} = depth of the receiver (animal) in meters
Phocidae	Hawaiian monk, elephant, and harbor seal	172 dB SEL (P_{WI})	177 dB SEL (P_{WI}) or 212 dB peak SPL	192 dB SEL (P_{WI}) or 218 dB peak SPL			
Otariidae	Sea lions and fur seals	195 dB SEL (O_{WI})	200 dB SEL (O_{WI}) or 212 dB peak SPL	215 dB SEL (O_{WI}) or 218 dB peak SPL			

5.2.2. Fish Criteria

5.2.2.1. PEAK PRESSURE LEVEL

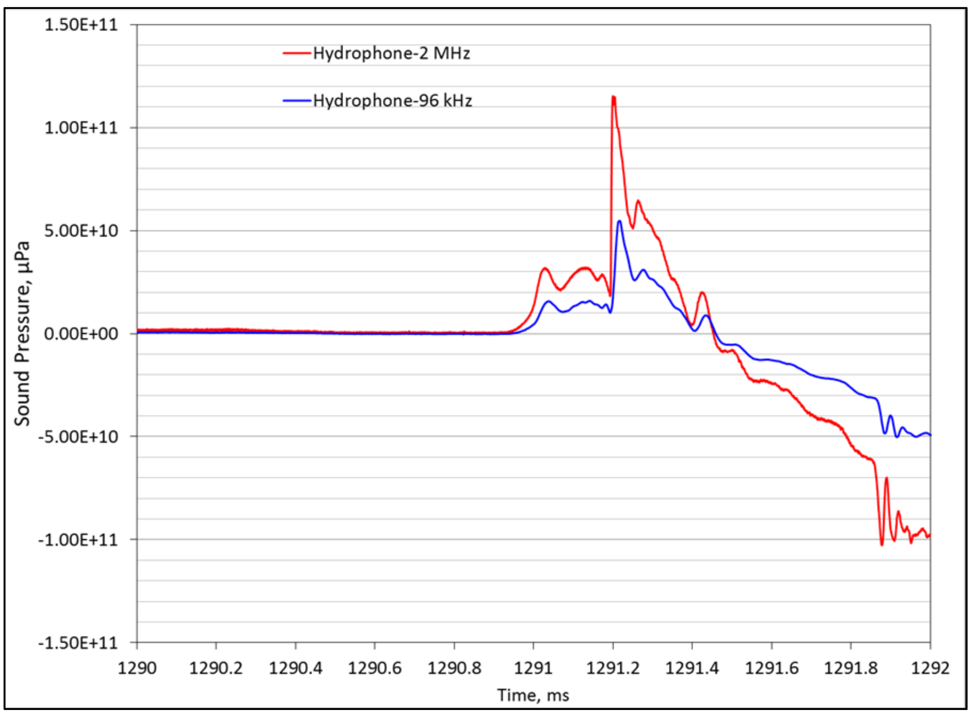
At this time, NMFS, CDFW and USFWS do not have specific peak pressure criteria for potential impacts on fish from underwater blasting. In the absence of such criteria, and after consultation with NMFS and CDFW (no fish species in the project area are regulated by USFWS), it was decided to compare the measured peak pressure level from the Pier E3 implosion to the existing criterion used for impact pile driving.

The pressure pulses generated by impact pile driving do not have rise times as fast as those generated by underwater blasts. While lower in amplitude, pile driving pressure fluctuations are longer in duration and as a result may have more energy when integrated over time. Further, for fish injury/mortality, the metric with the best correlation of underwater blast pressures to injury is impulse, not peak pressure, based on the research by Govoni et al. (2003) and Yelverton et al (1975). In developing the interim criteria for fish, it was recognized that the impacts from pile driving as compared to underwater blasts were significantly different and the pressure rise time could be a factor. After review of the work done by Yelverton et al. (1975) that involved underwater blasts, Hastings and Popper (2005) recommended cSEL as the metric most appropriate for assessing injury impacts of pile driving sound on fish. This was further affirmed by Hastings (2007) review of other work done that included blasts by Govoni et al (2003, 2007). ~~Based on the preference of impulse over peak pressure to assess impacts from pile driving on fish, became the initial basis for fish thresholds (Pogger et al. 2006; Carlson et al. 2007). However, it was also considered that alone may not completely capture impacts on fish. Therefore, a peak pressure level criterion based on this metric was added.~~ The cSEL criteria for fish were derived from blasting data sampled at a higher rate (approximately 1,000,000 samples per second) and with appropriate pressure transducers (Hastings 2007). However, the peak pressure level criterion was based on the nature of the peaks produced by pile driving that do not have the high frequency components that are seen in pressure fluctuations produced by blasting.

In 2005, Hastings and Popper published a paper assessing the Effects of Sound on Fish (Hasting and Popper 2005). Hastings and Popper concluded the body of data currently available is inadequate to develop anything more than the most preliminary scientifically supportable criteria for injury to fish from pile driving sounds (Hasting and Popper 2005). Therefore such a criteria was not proposed in their 2005 report (Hasting and Popper 2005). Instead, information from blasting and pure tone studies were used to develop recommendations for interim guidance (Hasting and Popper 2005). Hasting and Popper noted that such guidance should not be used for any signal other than pile driving (Hasting and Popper 2005). In 2006, Popper et al. recommended that interim criteria for injury to fish from pile driving be set at a peak sound pressure level of 208 dB Peak and an SEL level of 187 dB SEL (single strike) (Popper et al. 2006). This recommended interim criteria was based on findings from four studies; blasting and pure tone studies previously considered by Hasting and Popper in their 2005 report and one study by the Department using pile driving stimuli (Popper et al. 2006). In 2007 Hastings, Popper and Carlson recommended a slightly more stringent peak criteria of 206 dB Peak and cumulative SEL criteria of 189 dB cSEL for fish greater than 2 grams and 183 dB cSEL for fish less than 3 grams (Carlson et al. 2007, Buehler et al. 2007). Ultimately, in 2008 the Fisheries Hydroacoustic Working Group agreed in principle on an interim criteria for

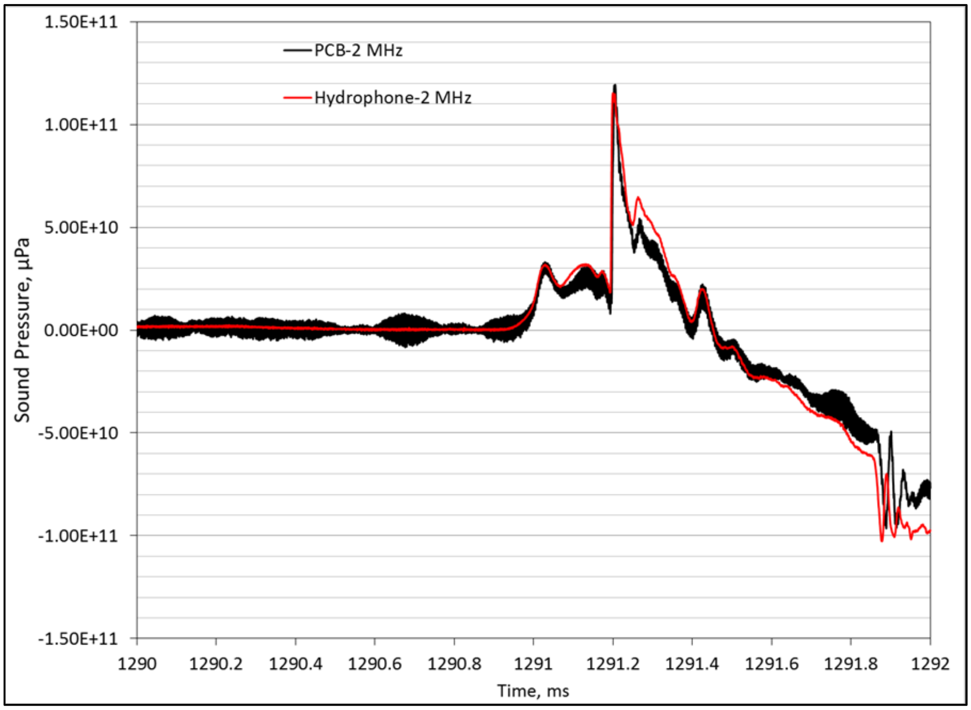
<u>injury to fish from pile driving activities of 206 dB Peak for all fish and a cumulative SEL criteria of 187 dB cSEL for fish greater than 2 grams and 183 dB cSEL for fish less than 3 grams (FHWG 2008).</u>

In practice, impact pile driving is typically measured with hydrophones and sampled at lower rates (typically less than 100,000 samples per second [S/s]). Figure 10 shows results from the Pier E3 implosion measuring the same event with the same sensor type (hydrophone) sampled at two different rates, high speed (2,000,000 S/s) compared to a lower speed (96,000 S/s). Sampling at the lower rates that are typically used for measuring peak pressures during pile driving may not capture the actual peak pressure when monitoring during blasting. When monitoring the Pier E3 implosion two types of sensors were used, hydrophones and pressure transducers. The technical differences between these sensor types are given in detail in later sections of this report. The peaks measured with either a pressure transducer or hydrophone using the same high sampling rate are both likely to capture the fast peaks generated by blasting (Figure 10 and 11). On



Note:
Pressure waveform at 500 feet from the east for a hydrophone sampled at both 2,000,000 and 96,000 samples/second.

Figure 10. Pressure Waveform at 500 feet from the East (1)



Note:
Pressure waveform at 500 feet from the east for a pressure transducer and hydrophone, both sampled at 2,000,000 samples/second.

Figure 11. Pressure Waveform at 500 feet from the East (2)

the other hand, use of higher sampling rates during blast monitoring could capture peaks that have a much faster rise time and may have been missed by using the lower sampling rates typically used to monitor impact pile driving. It is not the intent of this report to comment on the appropriateness of peak pressure criteria but rather to point out the differences that sampling rates could make in applying peak criteria to monitoring results. However, if peak pressure is going to be applied as a criterion for underwater blasts, development of criterion specific to blasts should be considered.

5.2.2.2. Cumulative Sound Exposure Level

For fish criteria based on the cSEL metric, the issue is not so ambiguous. As noted above, the cSEL criteria for fish were derived from underwater blast data. Further, the SEL produced with the hydrophone sampled at 96,000 S/s was nearly identical to that sampled at 2,000,000 S/s with the pressure transducer. As a result, the choice between using a pressure transducer or hydrophone to capture cSEL data is not critical.

5.2.3. Pier E3 Hydroacoustic Monitoring Executive Summary

Monitoring of the implosion was specific to two regions around Pier E3 with unique methods, approaches, and plans for each of these regions. These regions included the "near field" and the "far field." For Pier E3, the near field comprised of measurements taken within 200 feet of Pier E3, while the far field comprised of measurements taken at 500 to 4,000 feet. The underwater sound pressure monitoring occurred at numerous strategic positions around Pier E3 ranging in distance, including, at two locations within the BAS at approximately 23.5 and 24.5 feet, at four near field locations outside the BAS at distances ranging from 74.5 to 153 feet, and at seven far field locations ranging from 500 to 4,000 feet. Near field monitoring was conducted with PCB pressure transducers with data acquisition systems capable of measuring acoustic frequencies up to 1,000,000 Hz. Further away from Pier E3 at 500 feet, PCB pressure transducers and hydrophones capable of measuring acoustic frequencies up to 170,000 Hz were placed for underwater monitoring. Only the hydrophones were used for monitoring at the remaining far field locations. Because of the peak pressures that were expected within 500 feet, pressure transducers were required for data acquisition instead of the conventional hydrophones. In the near field, the dimensions of the pier were relatively large compared to the measurement distance. As a result, the relationship between sound pressure and distance from Pier E3 was complex, as the pressure from any one blast would depend not only on distance from the pier but also on the position of the blast along the face of the pier. Beyond 500 feet, sound levels were expected to display a more consistent logarithmic fall off with distance.

Figure 12 shows the results including the L_{pk} and cSEL measured at each location in the near field and far field. The logarithmic trend lines for the measured data points are also indicated along with established fish criteria for underwater impact pile driving. The trend line for the measured peak sound level is similar in shape to the estimated curve although offset by about 2 dB. The cSEL trend line decreases lower than the estimated curve with increasing distance and is about 14 dB lower at 4,000 feet. Noise levels are indicated by the representative colored lines.

Using the peak pressure level and cumulative sound exposure level results shown in Figure 12, the distances to the fish and marine mammal criteria were determined based on the logarithmic trend lines through the data points. A comparison of calculated distances and those determined from the monitoring measurements are shown in Figure 13 for the fish criteria and marine mammal TTS and permanent threshold shift (PTS) criteria. The results of Figure 12 indicate that the distances determined for the measured cSEL metrics were consistently below calculated estimates. For peak pressure, the distance determined from the measurements is slightly greater than that of the calculated estimates. However, per the discussion above, the sampling rates at the 500-foot and nearer locations used high speed data acquisition systems more capable of capturing the high speed peaks generated by the blast wave than the lower speed systems used at the monitoring points located at 820 feet from the pier and beyond.

5.2.4. Hydroacoustic/Underwater Pressure Monitoring Overview

As part of this demonstration, hydroacoustic monitoring was performed during the implosion at strategic locations around Pier E3. The purpose of hydroacoustic monitoring during the controlled implosion of Pier E3 was twofold: 1) to evaluate distances to specific fish and marine mammal impact noise criteria; and 2) to improve the calculation of underwater noise impacts that removal by controlled implosion of the remaining in-water piers may have.

The Pier E3 implosion consisted of 588 detonations of 8 different charge weights, ranging from 21 to 35 pound/delay. The duration of the event was 5.3 seconds from the first to the last detonation with individual charges separated by 9 milliseconds. Close to the pier, the individual blasts are distinguishable from each other. For any one measurement location, the highest peak pressure could occur at any time during the implosion event. During the demolition event, the pier was encircled with a BAS, which produced a stream of air bubbles surrounding the structure, as shown schematically in Figure 14 and in a photograph of the water surface around Pier E3 in Figure 15. Blast mats were positioned on the top and sides of the structure to control fly rock.

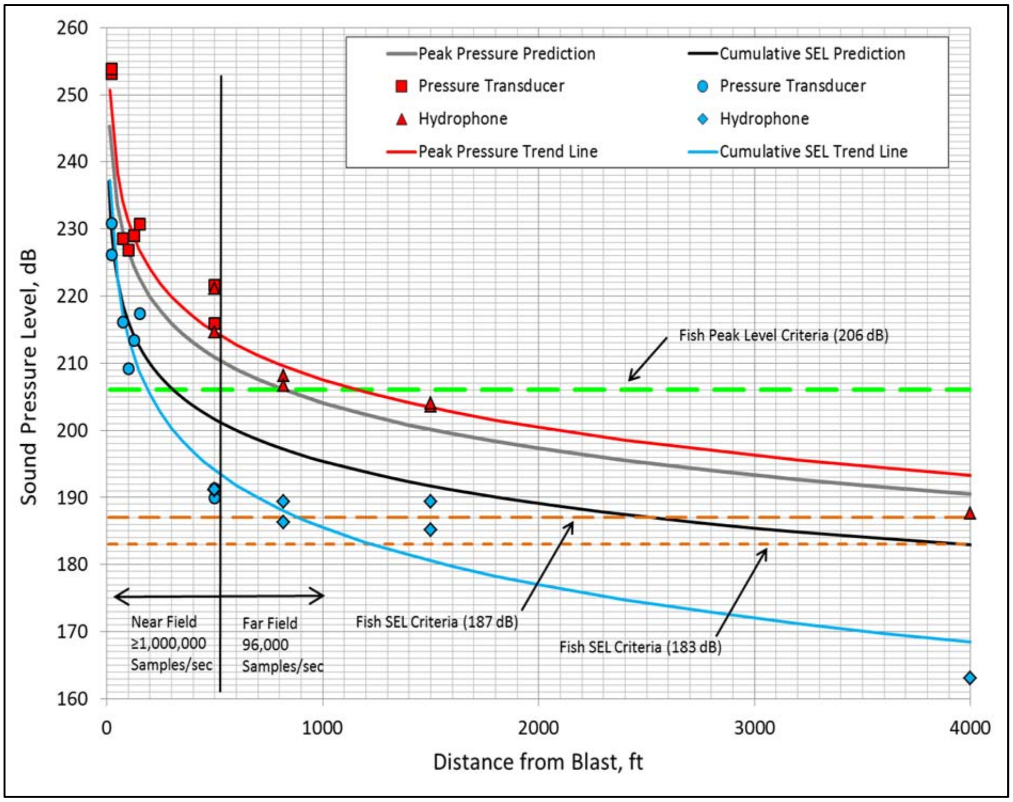


Figure 12. Summary of Peak Pressure Level and Cumulative Sound Exposure Level Results

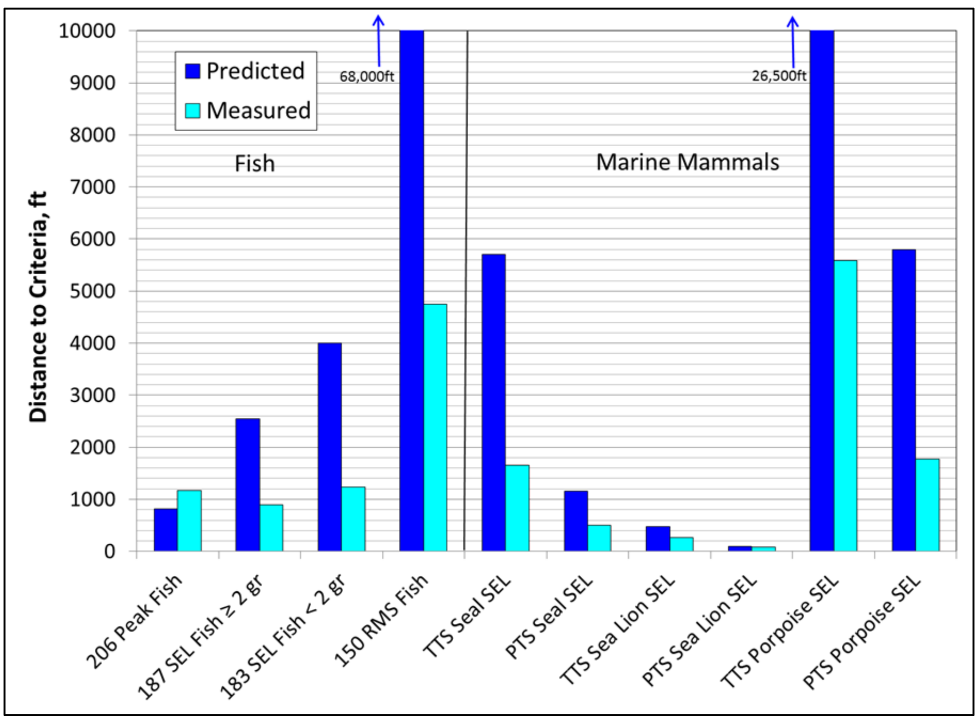


Figure 13. Summary of the Calculated Distances to Criteria and Those Indicated by Measurements

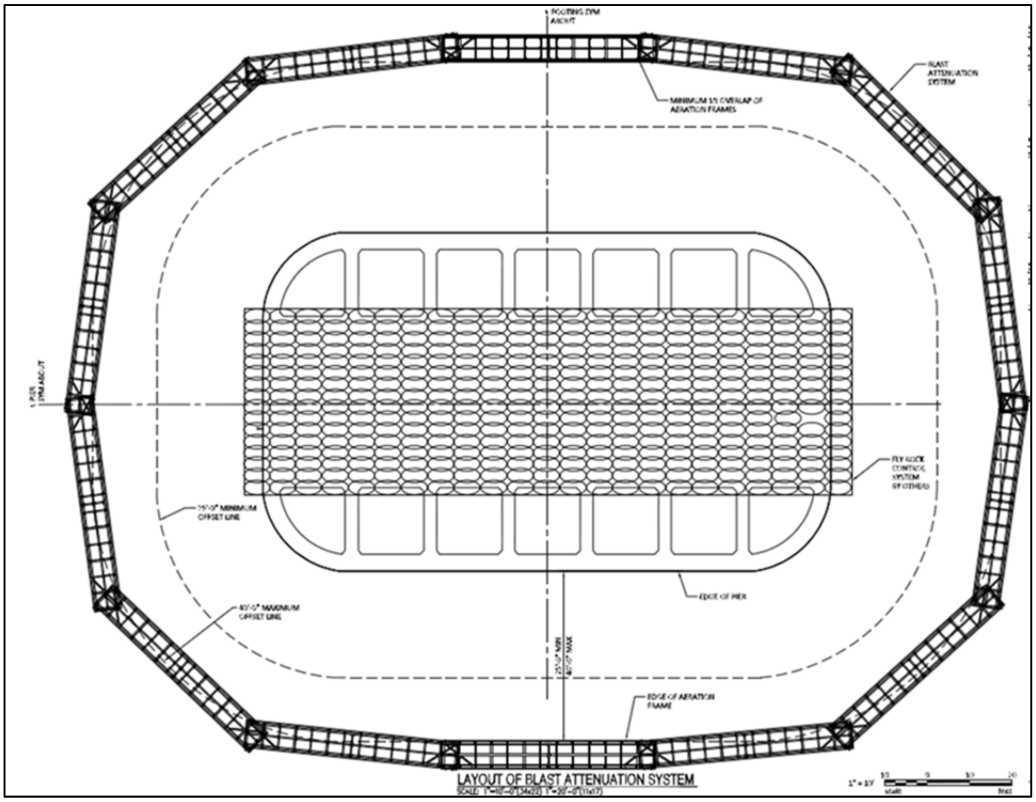


Figure 14. Blast Attenuation System Schematic

Figure 15. BAS Operating before the Implosion

As part of the process for permitting the demonstration implosion, underwater sound levels were calculated based on accepted theory for open water blasts. These equations were modified to account for confinement of the individual charges imbedded in the concrete structure and an assumed efficiency of the BAS to reduce the underwater blast pressures. A critical component of the analysis of the hydroacoustic results is the comparison between these estimated and actual measured levels. This report includes a description of the methods used to calculate the estimated hydroacoustic levels, a description of the monitoring measurements, a summary of the results, and a discussion on the implications for future calculated modeling and monitoring based on the Pier E3 implosion experience.

5.2.5. Estimated Levels

5.2.5.1. METRICS

To compare with appropriate marine mammal and fish sound criteria, the implosion's pressure signals were reduced and analyzed to obtain maximum peak pressure level, impulse, cSEL, and RMS levels. The pressure versus time signals from the near and far field monitoring locations were processed using the same algorithm to calculate the required metrics. Peak pressure level is defined as:

$$L_{pk} = 20\ Log_{10}\left(P_{pk}/P_{ref}\right) \qquad (1)$$

where L_{pk} is the peak level in dB, and P_{ref} is the reference pressure of 1 µPa. The acoustic impulse which is the time integral of the energy under the greatest positive peak pressure is given as:

$$Im = \int_{t_1}^{t_2} P(t)\ dt \qquad (2)$$

where $P(t)$ is the instantaneous positive pressure, t_1 is the start of the positive pressure corresponding to highest positive peak in the blasting event, and t_2 is end of the positive pressure. To calculate the impulse numerically, a discrete summation was used for the implosion of the form:

$$Im = \sum_{i=0}^{N} P_n t_n \qquad (3)$$

where t_n is the time resolution of the pressure versus time signal (e.g., 0.005 milliseconds for the 2,000,000 Hz signals), P_n is the pressure in a specific increment of time, and N is sufficiently that $N \times t_n$ covers the duration of the positive pressure pulse. Cumulative SEL is given by:

$$SEL_{cum} = 10\ Log_{10}\left(\int_0^T \frac{P^2(t)\ dt}{P_{ref}^2}\right) \tag{4}$$

where T is the duration of entire implosion, $P^2(t)$ is the instantaneous pressure squared, and P_{ref} is the reference pressure of 1 μPa. The numerical calculation used for the analysis of the near and far field locations is determined similarly to the impulse, except that integration is applied to the pressure squared and the integration time includes the entire blasting event, not just a single positive pressure pulse. Cumulative SEL is calculated as a summation by:

$$SEL_{cum} = 10Log_{10}\left(\sum_{i=0}^{t} \frac{p_i^2}{p_{ref}^2} \Delta t_i\right) \tag{5}$$

where Δt_i is the time resolution of the pressure versus time signal, p_i^2 is the pressure squared in a specific increment of time, and t is the total duration of the blasting event. For the SEL in general, the limits or duration of the summation are harder to determine than impulse values, as the waveform can contain both positive and negative pressures. The RMS level is given by:

$$p_{RMS} = \sqrt{\frac{1}{T_2-T_1}\int_{T_1}^{T_2} p^2\ (t)dt} \tag{6}$$

$$L_{RMS} = 20\ Log_{10}\left({}^{p_{rms}}/_{p_{ref}}\right) \tag{7}$$

where T_1 is the time at the beginning of the blasting event, and T_2 is the time at the end. Numerically, the RMS calculation is given by:

$$L_{RMS} = 20\ Log\ _{10}\left\{ \sqrt{\frac{1}{T_2-T_1}\sum_{T_1}^{T_2} p_i^2\ \Delta t_i} \Big/ p_{ref} \right\} \tag{8}$$

5.2.5.2. GENERAL ASSUMPTIONS

The blasting sequence was rather complex and is shown schematically in Figure 16. Blasts started in several interior walls of the southern portion of the structure followed by the outer walls of the south side. The blasts in the inner walls occurred just prior to the adjacent outer walls. The interior first, exterior second blast sequence continued across the structure, moving from south to north. As the blasting progressed, locations to the east, north, and west of the pier were shielded from the blasting on the interior of the structure from the still standing exterior walls of Pier E3. However, towards the conclusion of the blast, each direction experienced blasts from the outer walls that were not shielded.

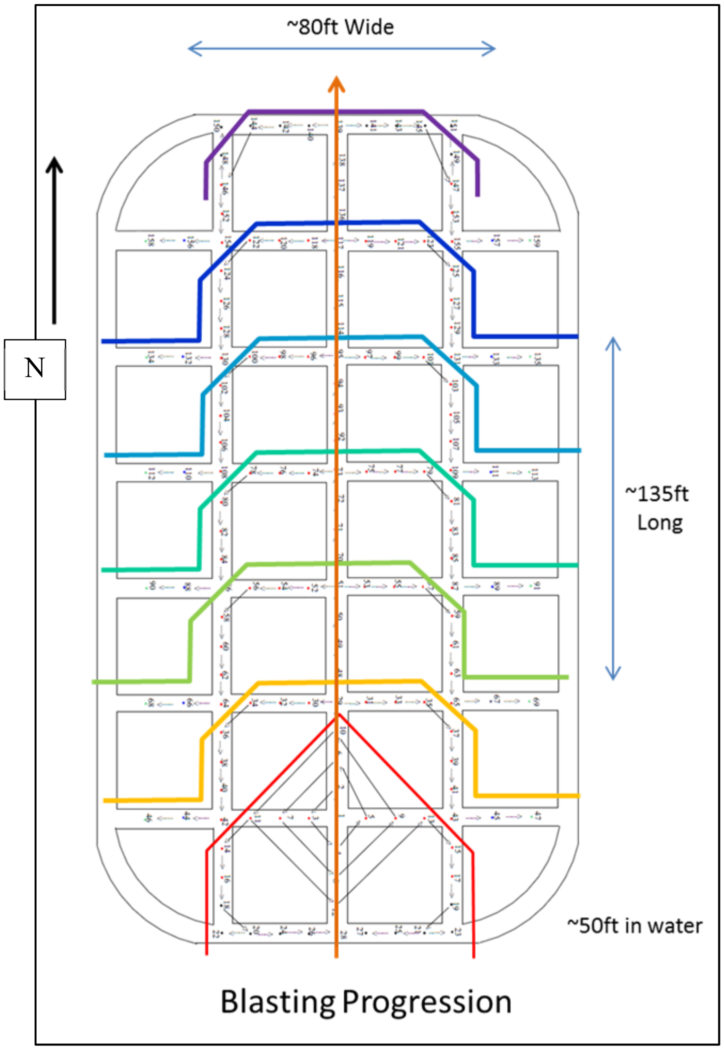


Figure 16. Sequence of the Firing of Individual Charges

To calculate P_{pk} and $P(t)$, several assumptions were made. For simplification, it was assumed that there was only one blast distance, and it would occur at the closest point on Pier E3 from the receiver point. In actuality for almost all explosions, distances from the blast were greater, as the portion of the pier that was removed via blasting was approximately 135 feet across and 40 feet wide. Based on these dimensions, the actual blast point could have been up to the diagonal distance of 141 feet farther from the receptor point used for the calculation. As a result, the calculated peak level was the maximum expected for one 35-pound blast, while the other levels were expected to be lower, depending on the distance from the actual blast location to the calculation point and weight of the charge. In other words, the pressure received at the calculation point would not be 588 signals of the same amplitude but would be from one at the calculated level for a 35-pound charge and 587 of varying lower amplitudes. Similarly, in the vertical direction, the location varies over a height of about 50 feet, and those blasts that were not at the same depth as the receiver would also be lower. This effect of variation in assumed blast-to-receiver distance would be most pronounced close to the pier, while at distances of about 1,000 feet or greater, the effect would be less than 1 dB.

In the calculations, it was also assumed that there would be no self-shielding of the pier as the explosions progressed. From the above discussion of the blast sequence, some shielding of the blasts along the interior of the pier is expected. However, the blasts that occurred in outer wall (towards the end of the detonation) would not be shielded for all blasts. A blast in the outer wall that has a direct line-of-sight to the receiver calculation point would not be shielded and would generate the highest peak pressure relative to the L_{pk} criterion. The cSEL and the RMS levels however, would be reduced to some degree by the outer walls until they are demolished, as these metrics are defined by the pressure received throughout the entire 5.3 second event. Because of the complexity of the blast sequence, this shielding effect was not considered in the calculated cSEL and RMS levels.

The explosives were placed in 2-3/4 to 3-inch-diameter holes drilled into the concrete pier structure. The outer walls of Pier E3 are nominally 3 feet and 11-1/2 inches thick and inner walls are nominally 3 feet thick. Individual blasts should not be exposed to open water and some confinement of the blasts was expected. For confined blasts, the calculated pressures can be reduced by 65 percent to 95 percent (Rickman 2000; Revey 2011; Nedwell and Thandavamoorthy 1992; Oriard 2002), corresponding to multiplication factors from 0.35 to 0.05, respectively. Based on a review of the available literature and recent data from similar explosive projects, a conservative confinement factor of K=7500 was assumed. This equated to a reduction in pressure by a multiplication factor of 0.3472.

Another assumption was to consider only the direct wave from an individual blast. In shallow water, the signal at the receiver point could consist of the direct wave, surface-relief wave generated at the water/air interface, a reflected wave from the bottom, and a wave transmitted through the bottom material, as shown in Figure 17 (USACE 1991). For estimating P_{pk} , only the direct wave was considered as it was expected to have the highest magnitude and will arrive at the receiver location before any other wave component. However, $P(t)$ after the arrival of the direct wave, peak pressure will be affected. The surface-relief wave is negative so that when it arrives at the receiver location, it will reduce the positive pressure of the direct wave and can make the total pressure negative at times after the arrival of the initial positive peak pressure. Because

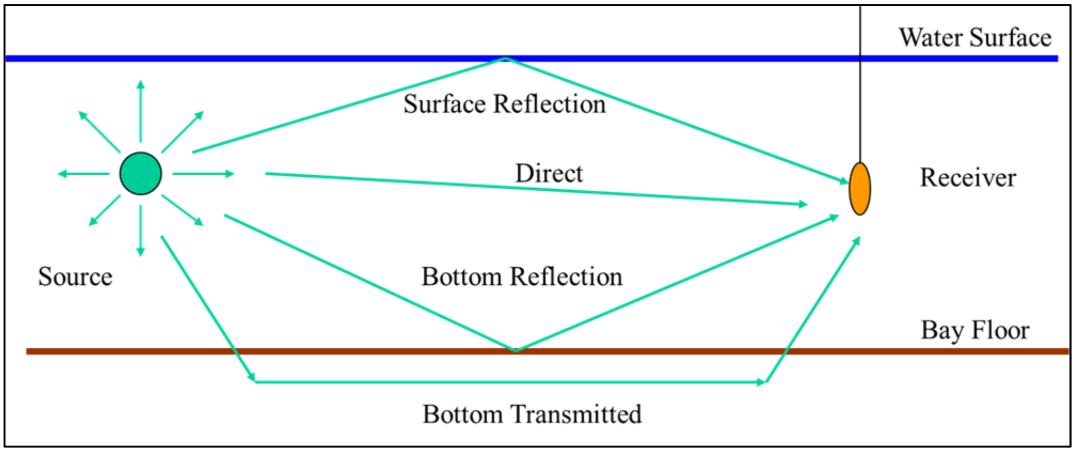


Figure 17. Propagation Effects in Shallow Water

the cSEL is a pressure-squared quantity, any negative pressure can also contribute to the cSEL. However, the amplitude and arrival time of the surface-relief wave depends on the geometry of the propagation case, that is, depth of water, depth of blast, and distance and depth of the receiver point. The effect of this assumption is discussed further in the section on cSEL.

5.2.5.3. CALCULATION OF PEAK PRESSURE

Peak pressures were calculated by following the modified version of the Cole Equation for calculation of blasts in open, deep water (Cole 1948). The peak pressure is determined by:

$$P_{pk} = K(\lambda)^{-).13} \quad (9)$$

where P_{pk} is peak pressure in psi, and λ is the scaled range given by $R/W^{1/3}$, in which R is the distance in feet and W is the weight of the explosive charge in pounds. A modified version of the Cole Equation has been documented in USACE Technical Letter No. 1110-8-11(USACE 1991) and is applicable to shallow water cases, such as that of the Pier E3 demolition[7]. The constant K factor multiplier in the USACE calculation is 21,600 for an open-water blast instead of the 22,550 from the original Cole Expression. This factor is slightly less (approximately 4 percent) than the original Cole. The decay factor (-1.13) used in the USACE modified equation remains the same as the original Cole Equation. To account for the confining effect of the concrete pier structure, a conservative K factor of 7,500 was used, corresponding to multiplying USACE P_{pk} by a factor of 0.3472. With a minimum delay between blasts of 9 milliseconds, the individual explosions were planned sufficiently apart in time to avoid individual blasts combining into a higher peak pressure. As a result, the peak pressure was taken as that calculated for the largest charge weight of 35 pound/delay. A BAS was specified in the blast plan. Based on the literature and recent results from similar projects, reductions in the pressure peak of 85 percent to 90 percent or more were expected. For determining P_{pk} in this analysis, a conservative reduction of 80 percent was used. Based on values of confinement, anticipated BAS performance, and the general assumptions above, the calculated peak pressures were expected to be conservative.

5.2.5.4. Calculation of Cumulative SEL Values

To calculate cSEL values as a function of distance from the blast, pressure versus time histories for all of the 8 charge weights were calculated for varying distances. The open-water equation used for these calculations was that modified by the USACE (1991), and based on methods pioneered by Cole (1948). Pressure as a function of time is given by:

$$p(t) = P_{pk} e^{-\left(\frac{t-t_a}{\theta}\right)} \qquad (10)$$

Where W is the charge weight and t_a is given as *R/5000* and θ is:

$$\theta = 6.0x10^{-5} W^{1/3} (\lambda)^{0.18} \qquad (11)$$

Some of the time histories produced by these equations are shown in Figure 18 for varying distances from the blast.

As discussed previously, there are other wave components that could have been considered in the cSEL calculation, including the surface relief wave, reflection from the bottom, and transmission through and re-radiation from the bottom. Little or no contribution was expected from the bottom, based on its sedimentary nature and previous experiences measuring noise during underwater pile driving in the area of the San Francisco Bay around Pier E3. The negative surface relief wave could be a factor in the cSEL calculation. This wave could either increase or decrease the cSEL, depending on its arrival time relative to the direct wave. For small differences in arrival time, the surface relief wave would decrease the total cSEL as a portion of the positive direct wave is negated by the addition of the negative surface relief wave. This is shown in Figure 19 for a blast and receiver depth of 30 feet and at a range of 1,000 feet. In this case, the surface relief wave essentially balances the direct wave so that the total cSEL is within a few tenths of a decibel of the direct wave only. For closer distances and when the receiver and blast locations are near the bottom, the total cSEL can become greater than the direct wave cSEL, but only by less than 3 dB. However, whenever the source or receiver is near the surface, the direct wave cSEL would be greater than the total cSEL and could approach being 10 dB or greater at distances beyond 1,000 feet. Because the

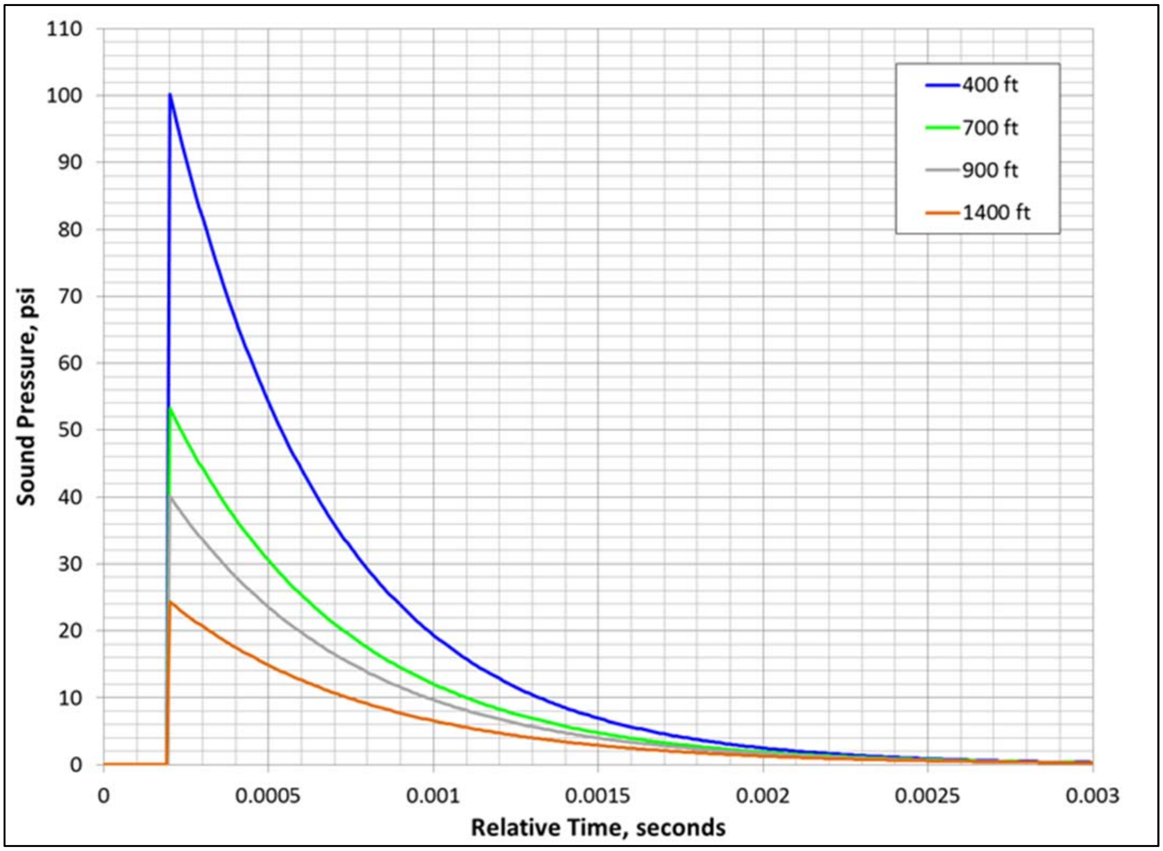
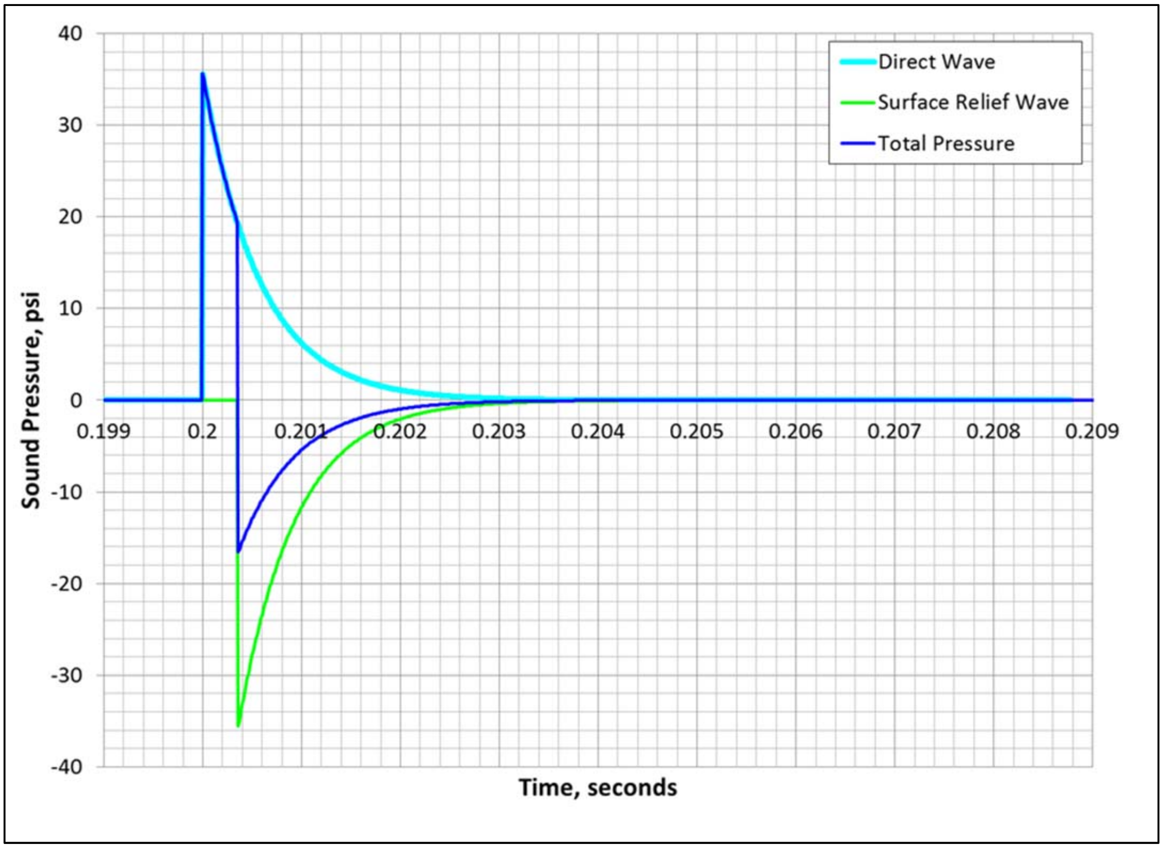


Figure 18. Calculated Blast Wave Time Histories for Different Blast Distances

cSEL values only approach the criteria at distances greater than about 2,300 feet, the surface relief wave is ignored in this analysis, knowing that the surface relief wave would only tend to produce lower cSEL values than the direct wave.

Considering only the direct wave, the time histories such as those in Figure 19 were squared and summed in a numerical version of Equation 2 to calculate single blast cSEL for each blast weight.

These calculations were then extended to distances out to 160,000 feet. To determine the cSEL for all 588 blasts, the single blast cSEL values, as a function of distance, were calculated for the other charge weights of 35, 32.5, 30, 29.6, 26, 24, 22.5, and 21 lbs. For each weight, the cSEL was determined by adding 10Log(N), where N is the number of the blasts for each weight. For example, 21.3 dB was added to the 35-lb single blast cSEL to account for 135 blasts of this charge weight. The values for all the charge weights are summarized in Table 8. These cSEL values for each charge weight were then summed (on an energy basis) to get the total cSEL for the unconfined blast sequence. To account for the confinement factor of 0.3472 (K=7500), 20Log(0.3472) or -9.2 dB was added to the unconfined values.



Note:
Calculated total pressure versus time history for combined direct and surface relief wave 1,000 feet from the blast with source and receptor 30 feet deep.

Figure 19. Calculated Total Pressure Versus Time History for Combined Direct And Surface Relief Wave

Table 8. Charge weights per delay, number of delays, and added level to accumulate number of blasts

lbs/Delay	Total Number of Delays, N	10Log(N), dB
35	135	21.3
32.5	24	13.8
30	135	21.3
29.6	111	20.5
26	24	13.8
24	12	10.8
22.5	12	10.8
21	135	21.3
Total	**588**	

The BAS would have an effect on the wave after a blast passes through it. In a research report by USACE in 1961, the performance of BAS was examined in detail. It was reported that a BAS reduces the peak pressure and elongates the pressure time history, as shown in Figure 19. It has also been found for an energy metric, such as cSEL, that the reduction produced by the BAS was equal to or greater than the reduction of the peak pressure. To estimate the reduction for cSEL values because of the BAS proposed blast design, cSEL was reduced by 80 percent. Effectively, this was done by reducing the cSEL by 20Log(0.20), or 14 dB. These cSEL values and those without the BAS were then compared to the fish criteria of 183 dB and 187 dB cSEL. Because the calculation of cSEL is based on the peak pressure, these calculated values for the direct wave component were expected to be conservative for the same reasons as described for the peak pressures.

5.2.5.5. CALCULATION OF RMS LEVELS

The RMS levels were derived from the cSEL values. Comparing Equations 2 and 3, the difference between cSEL and RMS is that RMS is divided by the interval from the start of the blast to the end of the blast (ΔT). The "end" of the blast is somewhat ill-defined, however. The cSEL is concluded when the received energy stops increasing with time. The time over which this occurs is not a factor. For RMS, time is a factor, and the RMS value is inversely related to ΔT. If ΔT is too short such that it does not include all of the energy from the blast, the RMS value may be overestimated. For calculations of RMS level for the Pier E3 blast event, the blast time of 5.3 seconds was used. The time over which energy is received, however, was probably slightly longer than this because of the elongating effect of the BAS and outward propagation of the wave. Given the 9-millisecond delay between detonations, the error should be quite small, and values calculated would be conservative. To calculate the RMS levels, 10Log($^1/_{5.3}$), or -7.2 was added to the cSEL values.

5.2.5.6. CALCULATION OF IMPULSE VALUES

To calculate positive impulse values, the expression originally developed by Cole for open water was used[8]. This expression includes only contributions from the direct wave neglecting any contribution from the surface relief, bottom reflected, and bottom transmitted, consistent with the assumptions used to calculate cSEL. In this case, impulse is given by Equation 12 with variables described previously:

$$I = 2.18 \times W^{1/3} \times \left(\frac{W^{1/3}}{R}\right)^{1.05} \qquad (12)$$

The impulse can also equivalently be calculated from wave forms, as shown in Figure 20. Equation 10 produces impulse values in psi-milliseconds, which were converted to Pa-sec by multiplying by 6.9 for comparison to the marine mammal criteria.

Unlike P_{pk} and cSEL, no reduction by the BAS was assumed for the impulse calculation. As shown in Figure 20, the area under the p(t) curve undergoes little change after passing through the BAS. The peak pressure is reduced, as noted previously; however, because the p(t) expands in duration, the area change is minimal. This behavior is well-documented in the literature. As discussed above, this is not the case for cSEL, which is determined by the area under the p2(t) curve.

5.2.5.7. Marine Mammal Weighting

For marine mammals, five groupings are considered in the criteria. These include Low-Frequency Cetaceans (LFII), Mid-Frequency Cetaceans (MFII), High-Frequency Cetaceans (HFII), Phocidaes (PWI), and Otariidaes (OWI). In the San Francisco Bay around Pier E3, the mammals of concern were identified to be Pacific harbor and northern elephant seals (PWI), sea lion (OWI), and harbor porpoise (HFII). The filters corresponding to these three groupings are shown in Figure 21. To apply these weightings, the Fast Fourier Transform (FFT) was calculated for the pressure time histories at each analysis distance (see Figure 18). Each FFT was then filtered using the frequency weighting specified for each group/species from Figure 21. Filter factors were then determined for each distance by subtracting the filtered result from the unfiltered FFT data and determining the overall noise reduction in decibels because of the filters. These filter factors were then applied to the cSEL determined for the entire blast event for each distance from Pier E3.

5.2.5.8. Results of Calculations

As discussed above, the peak pressure and cSEL values were calculated for each of the eight charge weights. An example of this is provided in Table 9 for a distance of 1,000 feet. Corresponding values were calculated for distances from 10 to 160,000 feet.

5.2.5.9. Fish Criteria

Plots of the calculated peak pressure level, cSEL, and RMS pressure level are shown in Figures 22 and 23, along with the respective criteria levels for fish. The intersection of the criteria lines and the calculated lines are also indicated, giving the calculated distance to criteria threshold values given in Table 9.

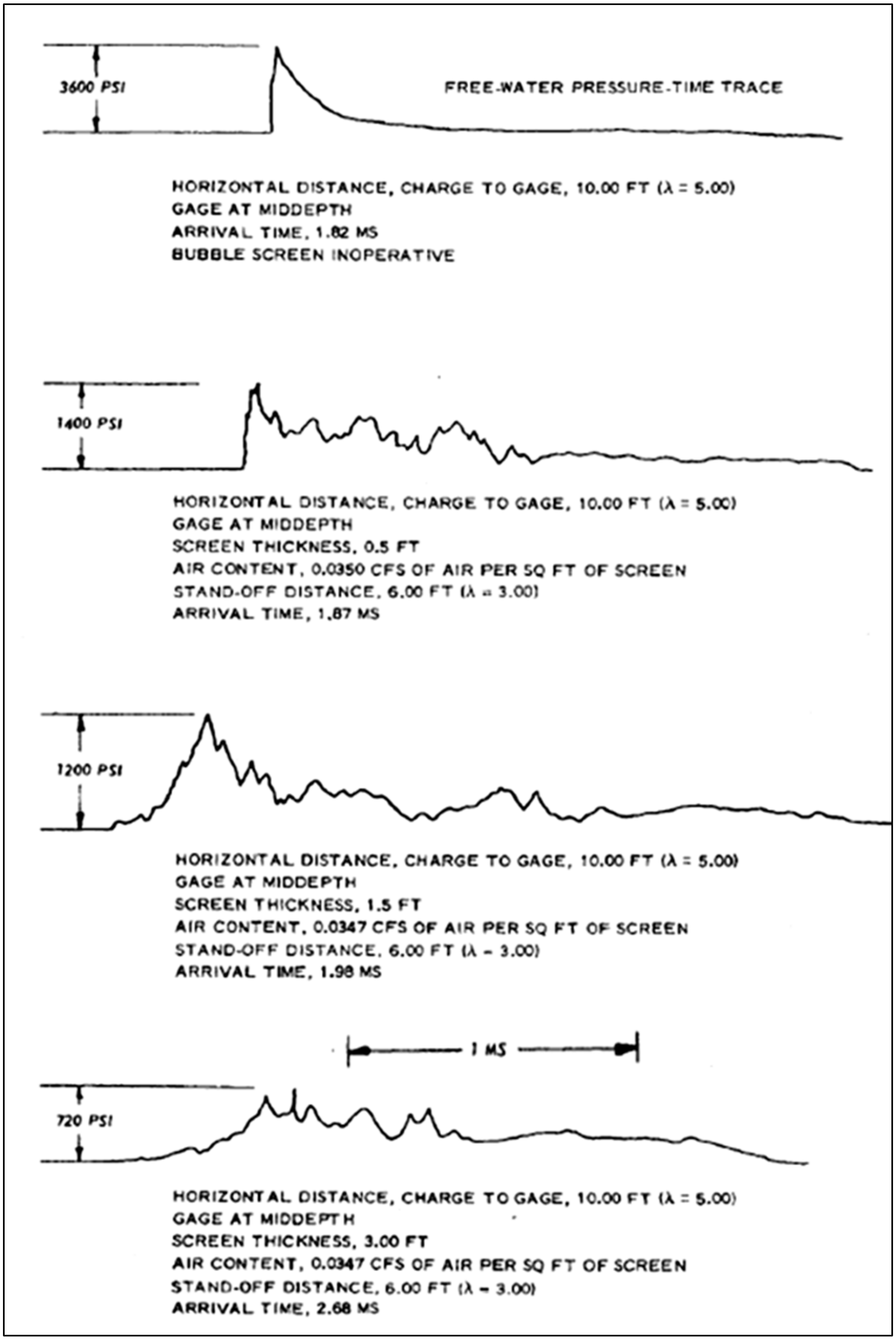


Figure 20. Effect of Bubble Screens of Different Parameters on Underwater Unconfined Blast

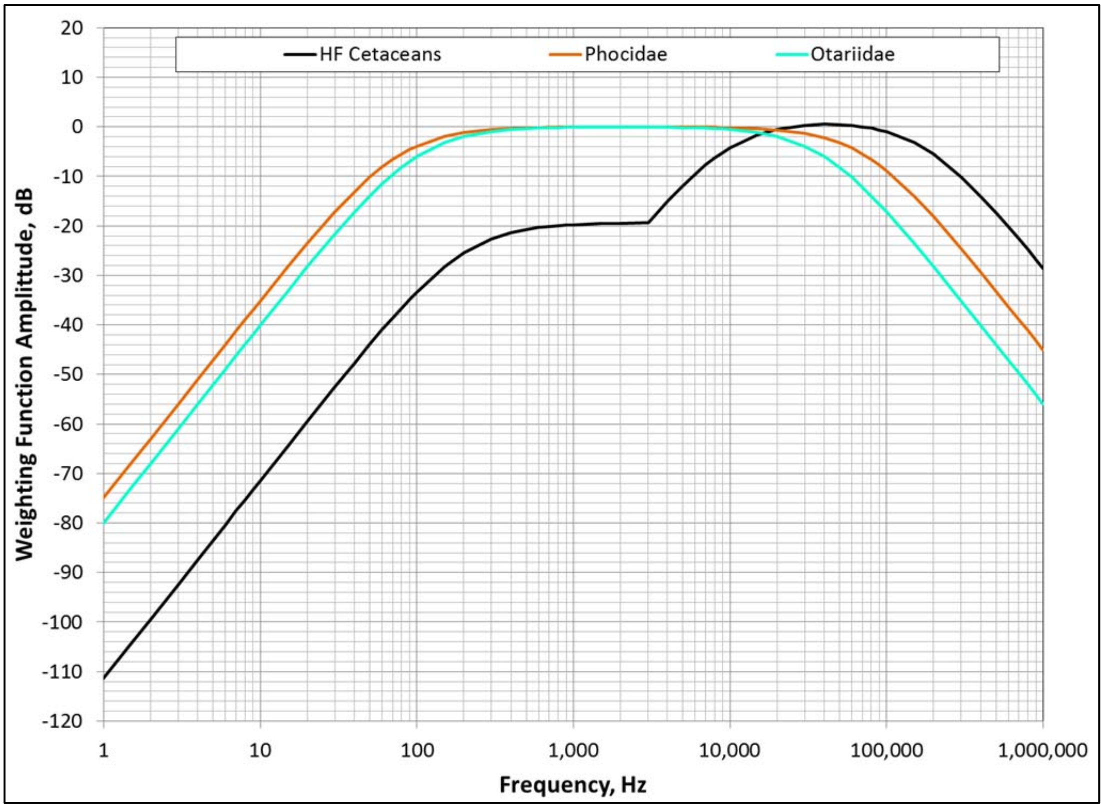


Figure 21. Weighting Functions for Marine Mammal Species of Concern for the Pier E3 Implosion

Table 9. Calculated peak pressure and single and cumulative SEL values for each charge weight at 1,000 feet

lbs/Delay	Peak Pressure, dB	Single Blast cSEL, dB	Total Number of Delays, N	10Log(N), dB	Cumulative SEL for Each Weight
35	204.1	168.6	135	21.3	189.9
32.5	203.9	168.3	24	13.8	182.1
30	203.6	167.9	135	21.3	189.2
29.6	203.6	167.8	111	20.5	188.3
26	203.1	167.3	24	13.8	181.1
24	202.9	166.9	12	10.8	177.7
22.5	202.7	166.6	12	10.8	177.4
21	202.4	166.3	135	21.3	187.6
Total			**588**		**195.4**

5.2.5.10. Marine Mammal Criteria

For marine mammals, three cSEL threshold values are prescribed corresponding to behavioral, TTS, and PTS. The values of the thresholds are also specific to each species grouping. The calculated cSEL values and specific thresholds are shown in Figures 24 through 26 for seals, sea lions, and porpoises, respectively. The distances to the each of

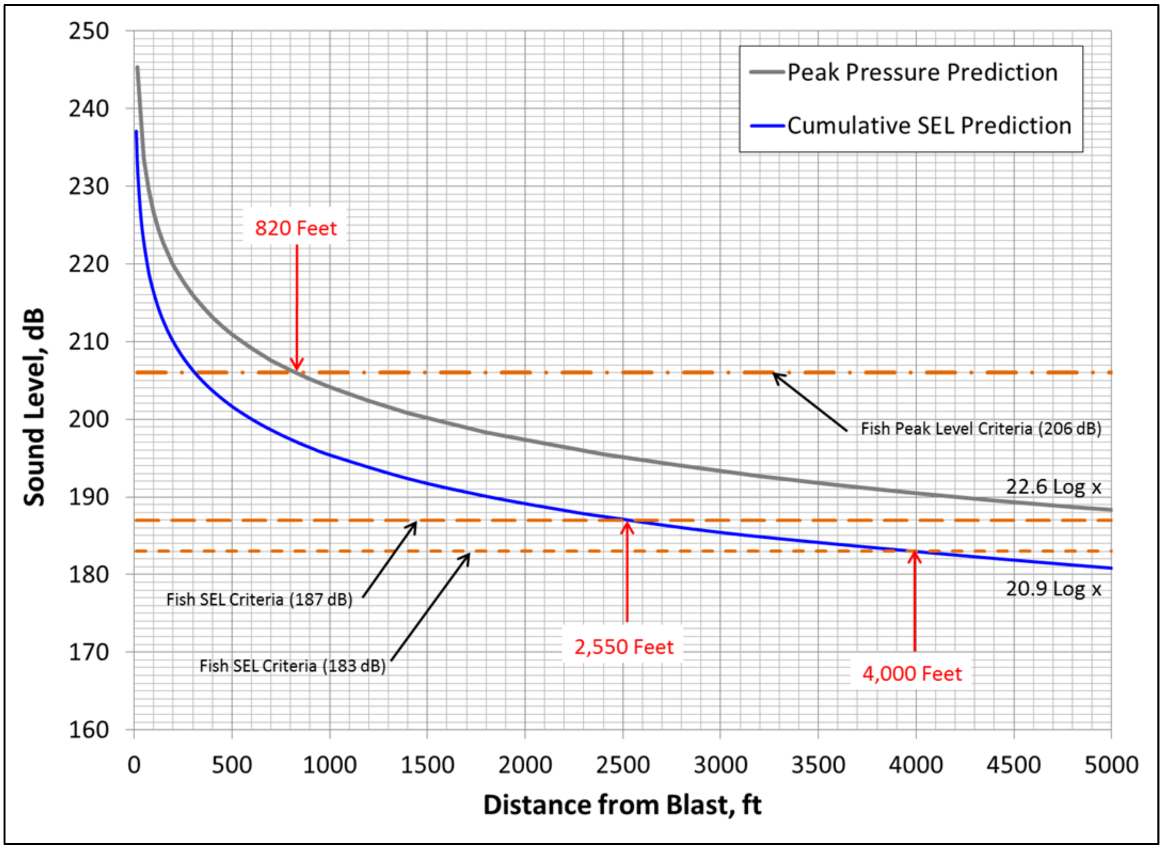


Figure 22. Calculated Peak Pressure Level and Cumulative SEL Values with Fish Criteria and Distances to Threshold Levels

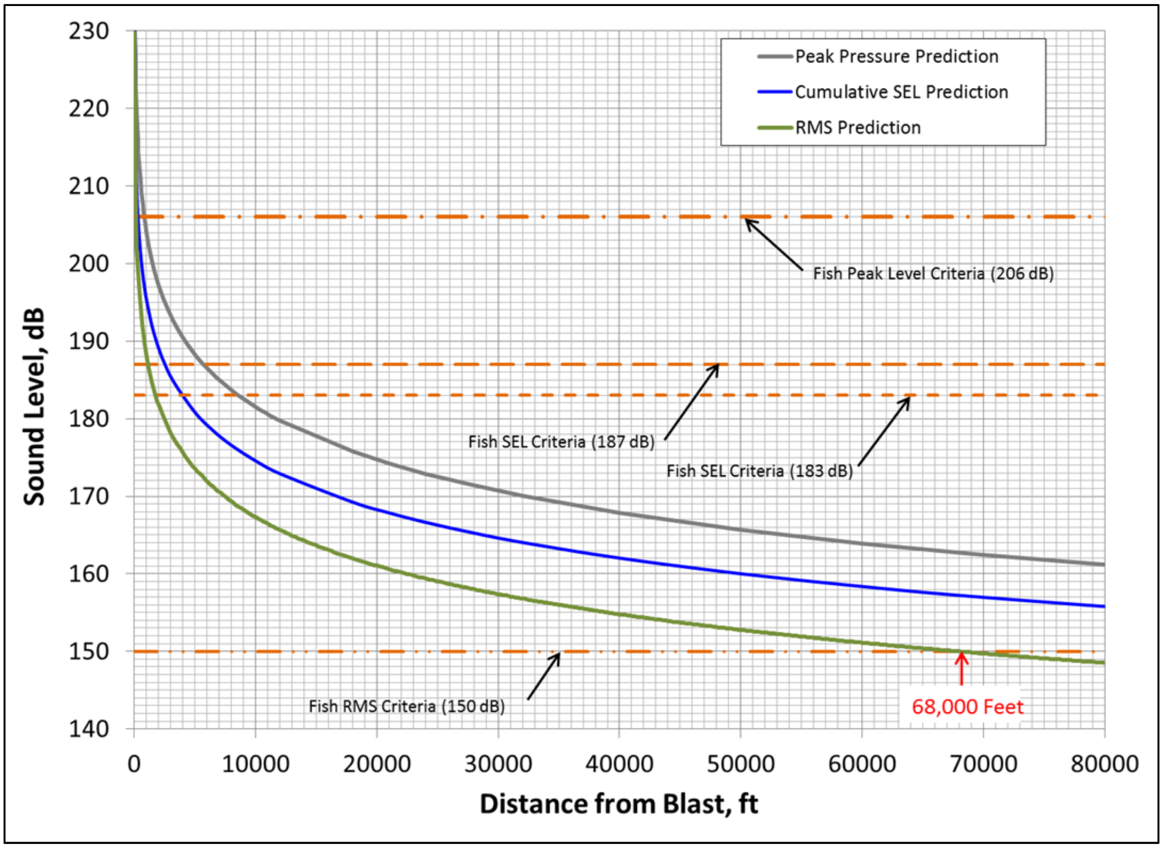


Figure 23. Calculated RMS Levels with Criteria and Distance to Threshold Level along with Peak Pressure Level and Cumulative SEL Values

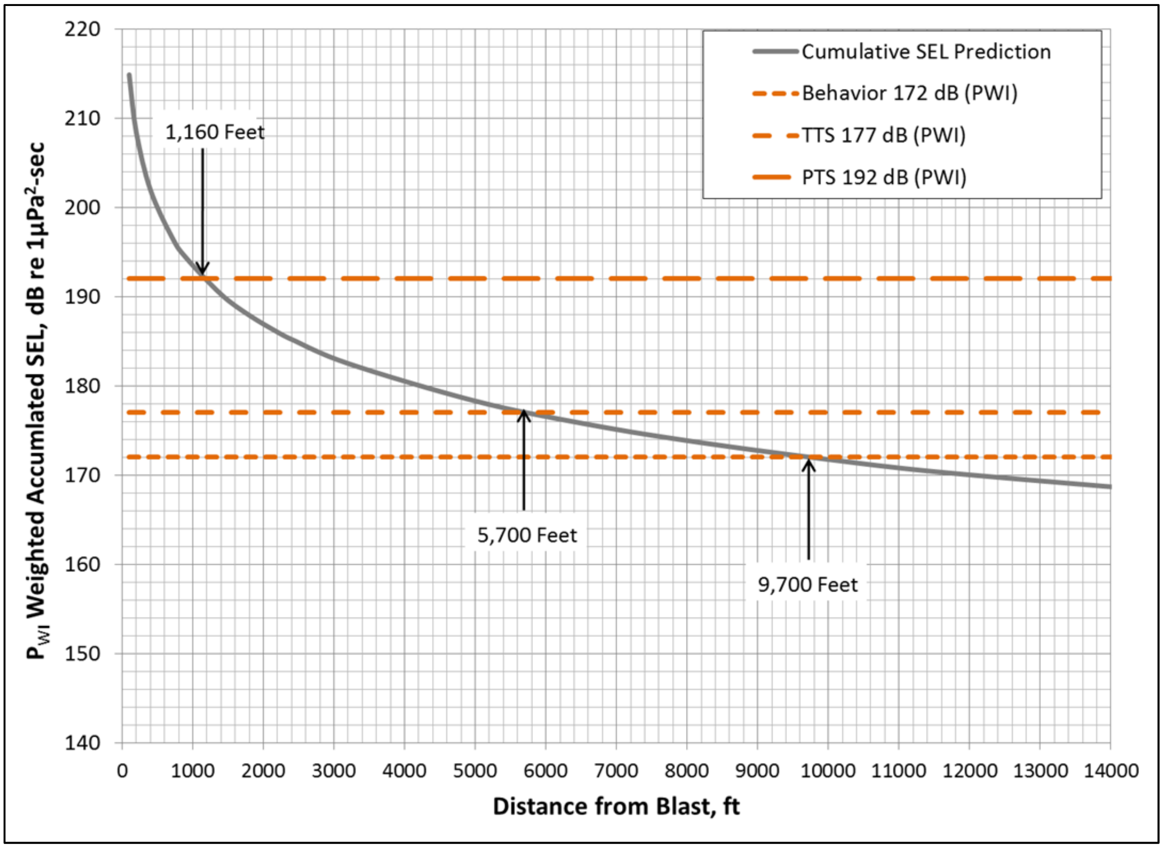


Figure 24. Calculated Cumulative P_{WI} Weighted SEL for Seals with Criteria and Distance to Thresholds Indicated

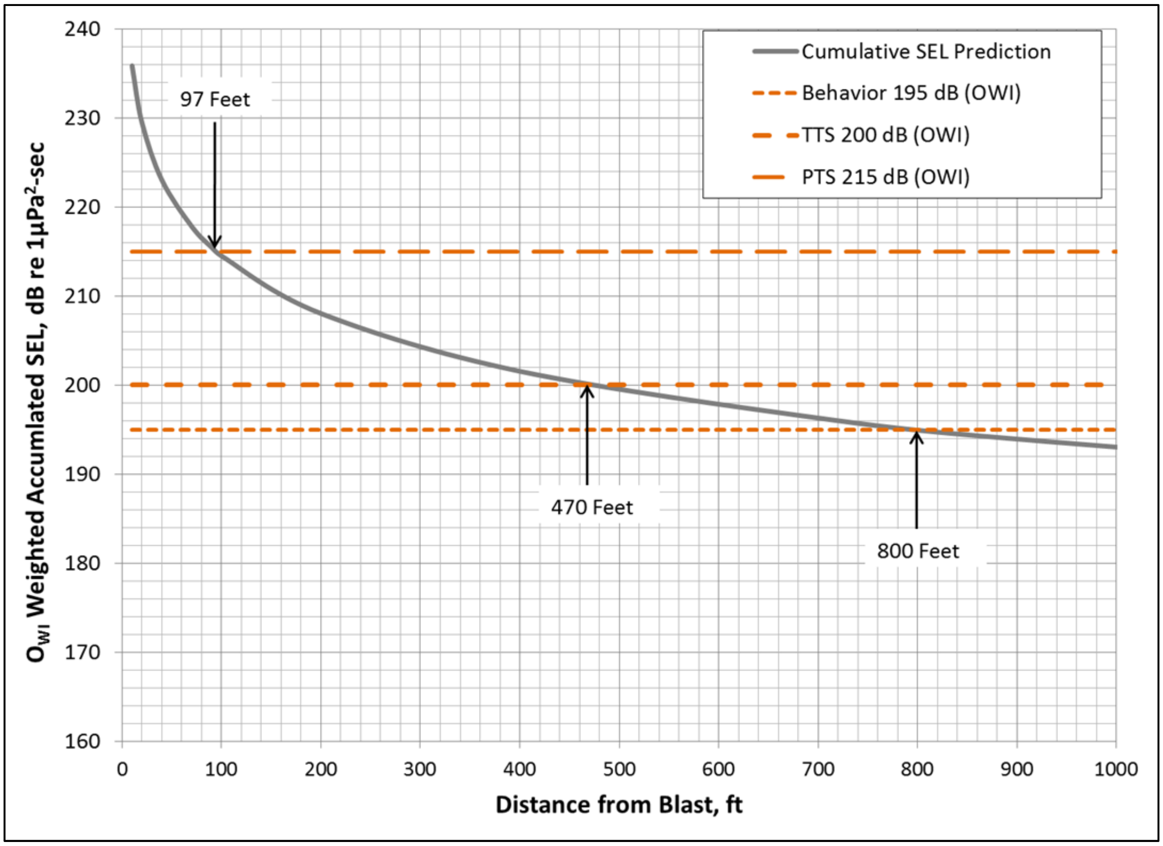


Figure 25. Calculated Cumulative O_{WI} Weighted SEL for Sea Lions with Criteria and Distance to Thresholds Indicated

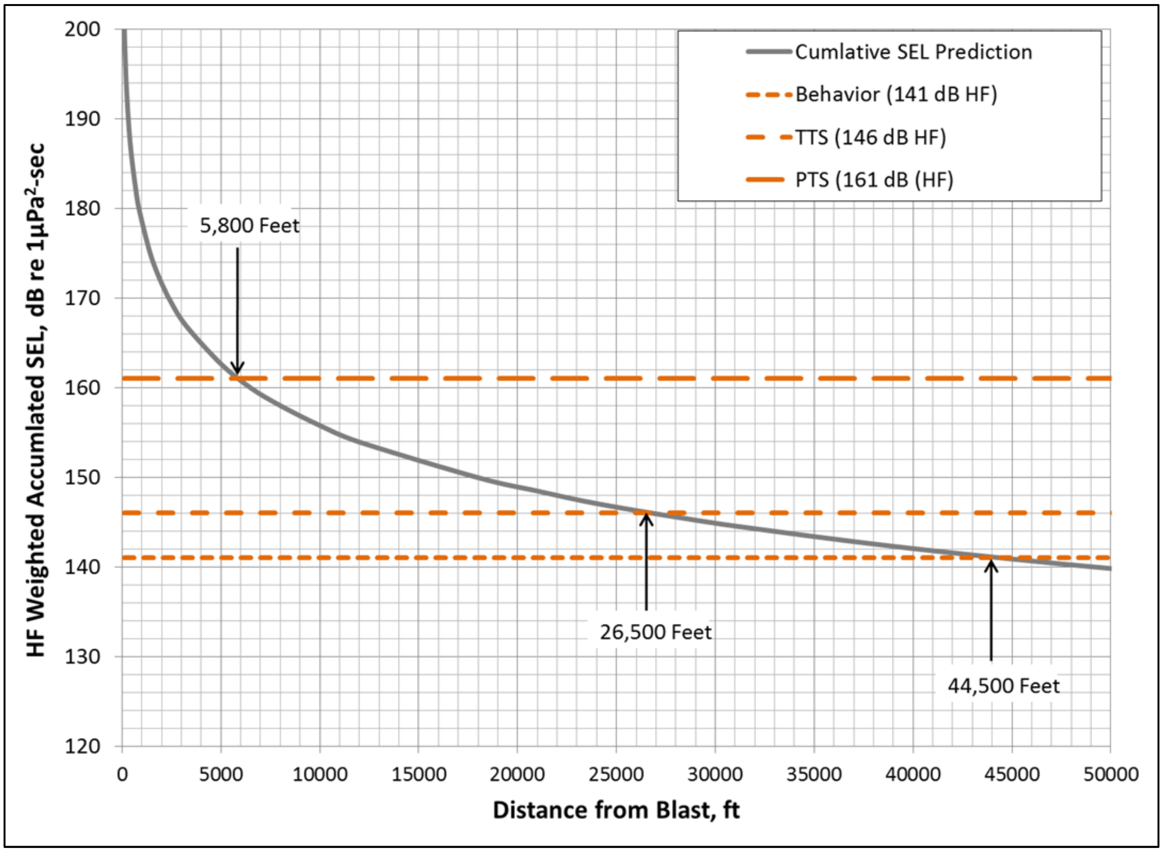


Figure 26. Calculated Cumulative HF_{II} Weighted SEL for Porpoises with Criteria and Distance to Thresholds Indicated

the thresholds for each of species are also shown in these figures. There are also criteria for gastro-intestinal (GI) tract injury, lung injury, and mortality. The GI threshold is quantified in peak pressure and the lung and mortality are impulse, based on mammal weight and depth. As a conservative measure, the thresholds for the GI injury, lung injury and mortality thresholds for all marine mammal species of interest were calculated using the average mass of a harbor seal pup (approximately 7 kilograms). This determination was made considering that the small mass of the harbor seal pup made it the most vulnerable (the smaller the mass, the less impulse can be absorbed before onset of injury) to impulse pressures and that the threshold for that single species could effectively be used as a conservative threshold for all the other species. Because harbor seal is the most common marine mammal species, the thresholds were developed with protection of that species at the forefront of the monitoring effort. In addition, this measure was considered conservative because harbor seals generally pup from March to June; November is not the time of year when harbor seals are pupping and harbor seal pups were not expected to be in the project area.

The GI threshold for all categories of species is a peak pressure of 237 dB. The calculated peak pressures, criterion level, and distance to threshold are shown in Figure 27. For lung damage, the threshold is expressed as an impulse value of 13.7 pounds per square inch-milliseconds (psi-ms) and applies to all categories. For mortality, the threshold is 32.02 psi-ms, and it also applies to all categories of marine mammals. The calculated impulse values, lung and mortality criterion level, and distance to these thresholds are shown in Figure 28.

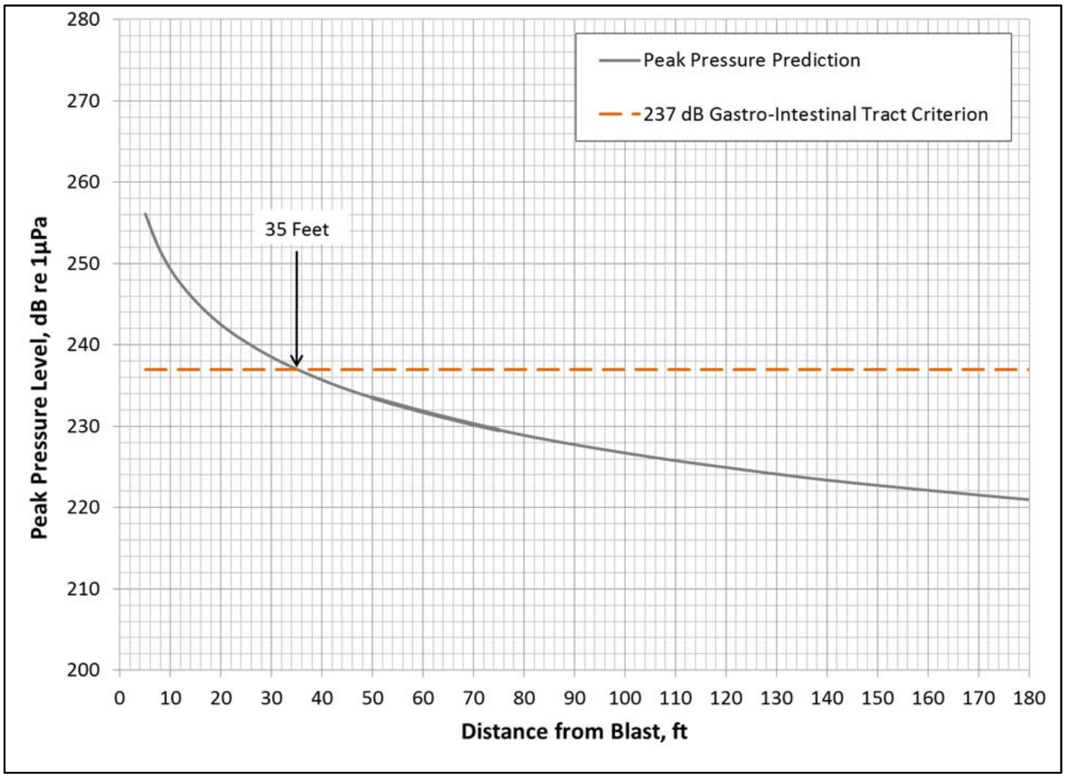


Figure 27. Calculated Peak Pressure Level with GI Criteria for All Marine Mammals and Distance to Thresholds Indicated

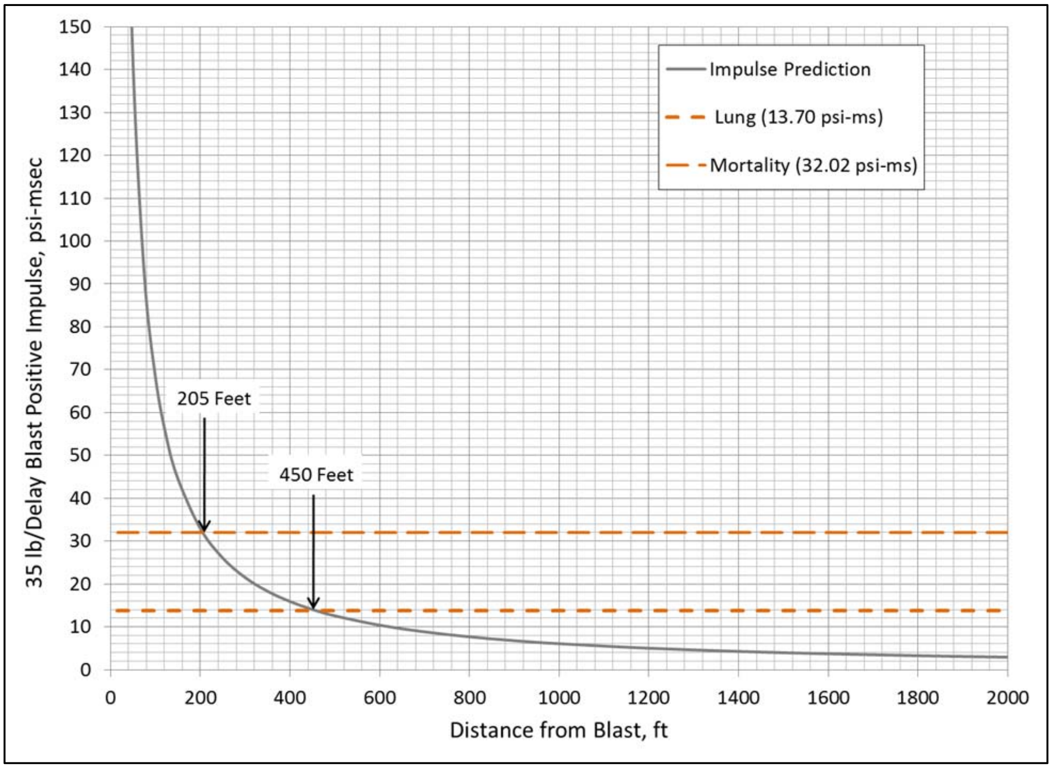


Figure 28. Calculated Impulse Values with Lung and Mortality Criteria for All Marine Mammals and Distance to Thresholds Indicated

5.2.6. Description of Hydroacoustic/Pressure Monitoring Plan

Monitoring of the implosion was specific to two regions around Pier E3 with unique methods, approaches, and plans for each of these regions. These regions included the "near field" and the "far field." For Pier E3, the near field comprised of measurements taken within 200 feet of the pier, while the far field comprised of measurements taken at 500 to 4,000 feet. Because of the peak pressures that were expected within 500 feet, pressure transducers were required for data acquisition instead of the conventional hydrophones. In the near field, the dimensions of the pier were relatively large compared to the measurement distance. As a result, the relationship between sound pressure and distance from the pier was complex, as the pressure from any one blast would depend not only on distance from the pier but also on the position of the blast along the face of the pier. Beyond 500 feet, sound levels were expected to display a more consistent logarithmic fall off with distance. The blasting contractor limited the personnel and materials within 1,500 feet of the implosion.

5.2.7. Measurement Locations

5.2.7.1. Near Field Locations

The near field monitoring plan consisted of 13 total monitoring locations in the north, south, and east directions from Pier E3 with the measurements taken at depths of 20 feet below the water surface, as shown in Figure 29. At three distances in the south line, measurements were also planned at depths 2 feet above the mudline resulting in a total of 16 pressure sensor locations (see Figure 29). The south line was selected to be along the line of the caged fish study out to a distance of 350 feet and to align with the far field monitoring line. Recordings of the pressure signals were to be performed with high speed devices on the east side barge. However, during preparation for the blast, it was determined that measurements at further out distances of 250 and 350 feet were not feasible because of recommendations by the sensor supplier on acceptable cable lengths to minimize electronic background noise. Near field monitoring was triggered electronically from the signal used to initiate the blast, and therefore, was time-synchronized with the detonation sequence.

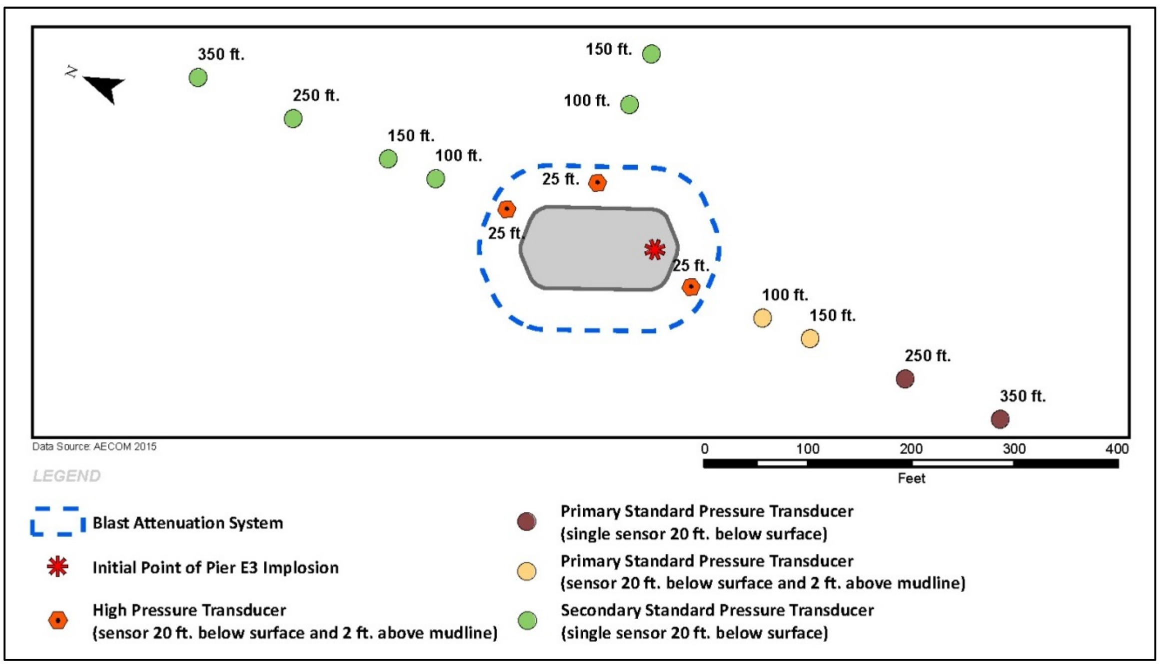


Figure 29. Near Field Monitoring Locations

For the implosion event, data was successfully acquired at five locations along the north line and at one location in the east line. The south line lost power prior to the implosion event, and no data could be collected. Along the north line, one monitoring location was positioned within the BAS at approximately 24.5 feet from Pier E3. The other locations along the north line were positioned at 74.5, 101, 126.5, and 153 feet from Pier E3 and outside the BAS, as shown in Figure 30. The successful measurement along the east line was located within the BAS, approximately 23.5 feet from the pier. The two planned locations outside the BAS along the east line were affected by flying debris and resulted in contaminated data, which could not be used for analysis.

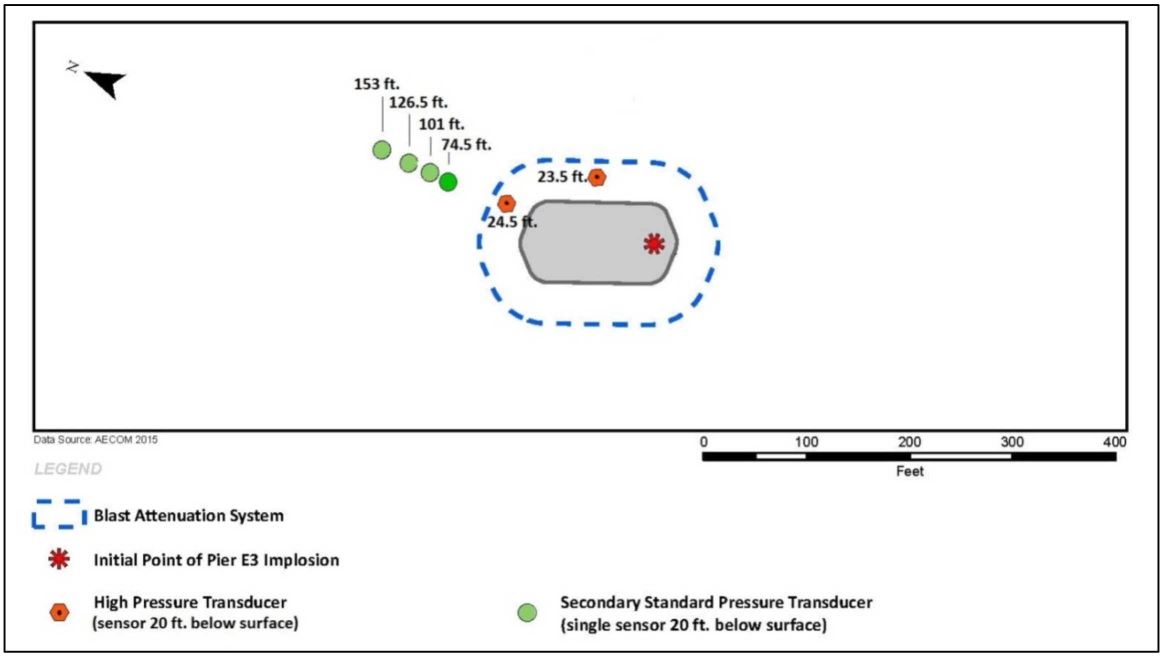


Figure 30. Deployed Near-Field Locations where Data was Collected during Pier E3 Implosion

5.2.7.2. FAR FIELD LOCATIONS

Far field monitoring was planned at 10 locations in the east, south, and southwest directions, with the south and east lines measured at a logarithmic progression of 500, 1,000, 2,000, and 4,000 feet. The south line was selected to be a continuation of the south near field line and to be in deeper water. The east line was selected to provide comparable data to the south line, but in shallower water. It was of interest to examine the sound propagation differences between the shallower and deeper water to determine if significant differences occur as the remaining piers to the east are in shallower water. Two locations in the southwest direction were planned at distances of 500 and 1,000 feet that would complement the data at the same distances to the south and east. At the 500 feet locations, it was planned that the data would be taken from boats with the instrumentation operated by hydroacoustic monitoring personnel. This plan was later modified because of a requirement that a buffer zone of 1,500 feet surrounding Pier E3 be maintained in which only personnel directly involved with the blasting were allowed. A caged fish study was carried out by the Department within the near field and portions of the far field monitoring range during the implosion to examine any impacts from the implosion on fish. The caged fish study was designed to run along the same transect as the hydroacoustic monitoring lines. Obtaining data toward the end of the caged fish line, located at approximately 820 feet from Pier E3, was also important. The 11 resultant planned monitoring locations are shown in Figure 31. Because of the 1,500 feet buffer limitation, it was determined that measurements at the closer distances would need to be unattended for safety reasons.

Figure 31. Proposed and Deployed Locations of All Far Field Monitoring Points

For the implosion event, data was successfully captured at a total of seven locations in the south and east directions shown in Figure 32. Because of the distances measured in the far field, monitoring operations could only be triggered by the received acoustic signal. The high speed recorders were programmed to trigger after a predetermined voltage threshold was exceeded. Using a pre-trigger recording feature, the recorders did capture the signal 0.8 seconds prior to the actual trigger point and continued to capture data for a

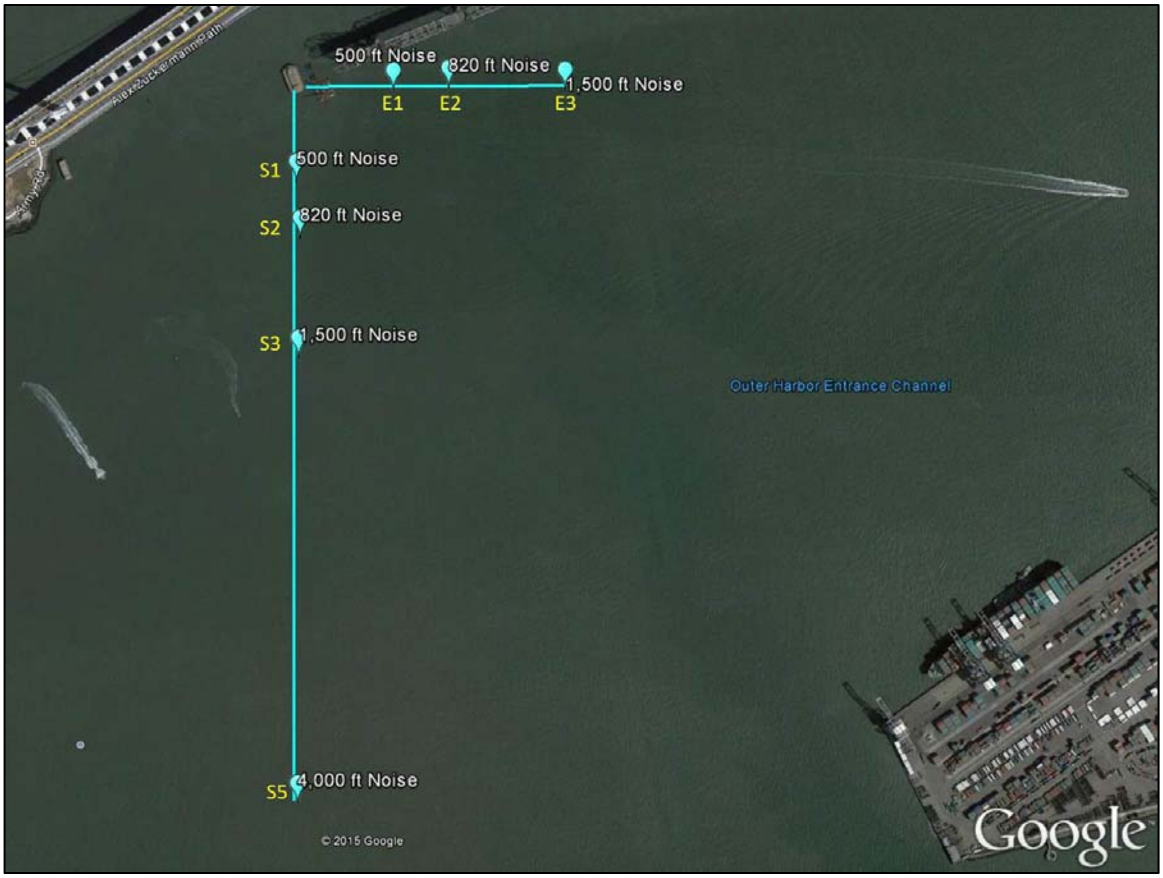


Figure 32. Far-Field Deployed Locations where Data was Collected during Pier E3 Implosion

total of eight seconds. At all other far field positions, hydroacoustic signals were recorded during the entire event, starting when the hydrophone was placed into position and ending when the hydrophone was collected after the event. Along the east line, data was measured at 500, 820, and 1,500 feet. Along the south line, data was measured at 500, 820, 1,500, and 4,000 feet. For these locations, all of the monitoring was conducted at depths of 20 feet from the water surface or at mid-depth for shallower locations. Data for three locations (southwest 820 feet, east 2,500 feet, and east 4,000 feet) are not available as the recorders shutdown prior to the implosion after approximately 14 hours of operation because of memory issues. At 2,500 feet in the south direction, the buoy supporting the measurement recorder could not be found and was presumed to be struck by a water craft operating in the area.

5.2.8. Instrumentation

5.2.8.1. Near Field Monitoring

Within the BAS where pressures from the implosion were highest, the rise time of the pressure signals were very short and required high speed acquisition of data. To meet this requirement, PCB 138A05 high pressure transducers capable of measuring up to 5,000 psi were used. Outside the BAS at each near field location, PCB 138A01 pressure transducers capable of measuring up to 1,000 psi were used to improve the measurement resolution. These transducers were capable of capturing acoustic frequencies greater than 1,000,000 Hz. Because of the design of the pressure transducers, there is no method for field calibration of either of these pressure transducers. For these pressure transducers, the manufacturer supplied calibration was obtained within six months of the implosion. The voltage signals proportional to pressure were recorded by an eight channel MREL DataTrap II high speed recorder sampling at 1,000,000 S/s (one record per 0.001 milliseconds) per the Near Field Hydroacoustic Monitoring Plan. With the expected rapid rise time of pressure from individual blasts in the implosion event, the sampling rate of 1,000,000 S/s was determined to be the appropriate for capturing the true peak pressures.

5.2.8.2. FAR FIELD MONITORING

500 Feet Locations

At both of the 500-foot monitoring locations, high speed Dash 8HF recorders were used to capture the voltage signals proportional to pressure. These units provided a sampling rate of 2,000,000 S/s. The input signals were measured using two methods. The first consisted of a PCB 138A01 pressure transducer (as used in the near field monitoring outside the BAS), which was powered by a PCB 482A22 signal conditioner with an acoustic frequency response range greater than 1,000,000 Hz. The second signal was produced by a Reson TC4013 hydrophone with an upper acoustic frequency range of 170,000 Hz. To avoid extraneous noise, the output of the hydrophone was passed through a PCB 422E04 in-line charge converter limited to an upper acoustic frequency range of 100,000 Hz. This signal was then conditioned with a second channel of the PCB 482A22. The output of each system was split and fed into two channels of the recorder set to two different voltage ranges to capture an optimize signal. As the more distant monitoring locations used hydrophones only, the 500-foot systems were used as a comparison point between the high speed/high frequency pressure transducer system and the more moderate speed hydrophone-based systems. The hydrophone systems are more sensitive, provide less electronic noise floor issues, and are more suitable for the lower levels estimated for the distant locations.

Because of the large number of samples generated at 2,000,000 samples per second, the Dash recorder could not be left continuously collecting data without quickly filling its memory. As a result, the Dash recorder was triggered by the incoming signal of blast sequence. This trigger was armed when the unit was deployed about two hours prior to the implosion. The Dash recorder did not have internal electrical power and had to be powered with heavy-duty batteries supplying 12-volt DC power to an inverter, which in turn provided 110-volt AC power to the recorder. The signal conditioner was also powered by external batteries. As a backup to the high speed recorder, a solid state Roland R-05 audio recorder captured the hydrophone signal as well. The sampling rate for this recorder was 96,000 samples per second. The input to this recorder was split at the output of the signal condition with one signal going to the Dash recorder and one to the Roland.

The complete recording systems with batteries were housed in 48-gallon, weather-resistant plastic storage containers. For the two 500-foot positions, the recording systems were placed in skiffs anchored at each location where previously deployed buoys marked the position. After being transferred to the skiff, the separate pressure transducer and hydrophone lines were lowered into the water with a weighted line to a depth of 20 feet and attached to the skiff. This deployment method reduced any possibility of flow induced vibration of the lines producing extraneous strumming sounds in the recordings. Because the measurements occurred during slack tide, no additional measures were necessary to reduce strumming effects. Then the high speed Dash recorder trigger was armed, and the Roland solid state recorder was turned on to begin continuously recording signals through the time of the blast.

820 Feet Locations

At the 820-foot locations to the south and east, unmanned rafts were deployed and secured to an anchor line attached to a buoy about two hours prior to the implosion. For the south position, a system identical to those at the 500-foot locations was placed into the raft. Prior to the placing the raft into the water, the Dash recorder was installed, powered, and armed. The raft was then placed into the water over the side of the boat with some difficulty, and in the process, power to the recorder was lost. It was not possible to confirm the status of the instrumentation after the raft was in the water. However, the backup Roland recorder was not affected and produced usable data. For the east location, the acquisition system consisted of only a Roland recorder with a Reson TC4033 hydrophone, a PCB 422E13 charge converter, and a PCB 482A22 signal conditioner. Compared to the TC4013, the TC4033 had more sensitivity but is limited to a maximum acoustic frequency response of 140,000 Hz. Similar to the 500 feet positions, the hydrophone lines were loosely attached to the raft and suspended down a separate weighted line to a depth of 20 feet.

1,500 Feet Locations

At 1,500 feet, attended monitoring systems in the south and east direction were deployed from boats alongside buoys that were set out and positioned the afternoon before the implosion. Two engineers with multiple years of experience in hydroacoustic monitoring were on each boat. The data acquisition systems used were similar to those at the east 820 feet location, except that TC4013 hydrophones were used at these locations. The voltage signals were also captured with Roland R-05 solid state recorders.

4,000 Feet Location

At 4,000 feet in south direction, an autonomous unit was deployed about one hour prior to the implosion. This unit consisted of a TC4013 hydrophone, a PCB 422E13 charge converter, and a PCB 480E09 signal conditioner all housed in a water-tight cylindrical case about five inches in diameter and 12 inches long. The unit was guided down the anchor and buoy using a separate, weighted line that was secured to the buoy. The autonomous unit was positioned at a depth of 20 feet.

5.2.9. Data Processing

5.2.9.1. Calibration

The various pieces of equipment used for measuring the implosion required different calibration methods. For the PCB 138A05 and 138A01 pressure transducers, the sensitivities supplied by the manufacturer were used to convert the measured voltages into pressure versus time. The accuracy of the MREL DataTrap II and Dash 8HF recorders were supplied by the sources of the recorders. For the TC4013 and TC4033 hydrophones, direct calibration was possible using a traceable pistonphone (calibrator). For these hydrophones, a G.R.A.S. 42AC Pistonphone, high pressure, Class 1 was used. This pistonphone was calibrated to produce a 165.3 dB sound pressure level at 250 Hz when used with a G.R.A.S. RA0078 Calibration Coupler for the TC4013. When used with G.R.A.S. RA0043 coupler, the pistonphone produces a level of 156.5 dB for the TC4033. For systems using the Roland R-05 solid state recorder, the calibration tone was directly recorded and used to determine hydrophone sensitivities for the complete instrument chain. The resultant sensitivities are shown in Table 10.

Table 10. Summary of resultant sensitivities for each far field sensor

Direction	Distance	Measurement Transducer	Sampling Rate	Sensitivity
East	500 feet	PCB	2,000,000 S/s	5.208 mV/psi
		Hydrophone	2,000,000 S/s	1.0436×10^{8} µPa/mV
		Hydrophone	96,000 S/s	2.1656×10^{8} µPa/mV
	820 feet	Hydrophone	96,000 S/s	4.4046×10^{7} µPa/mV
	1,500 feet	Hydrophone	96,000 S/s	2.6334×10^{7} µPa/mV
South	500 feet	PCB	2,000,000 S/s	5.005 mV/psi

		Hydrophone	2,000,000 S/s	1.0436×10^8 μPa/mV
		Hydrophone	96,000 S/s	3.7187×10^8 μPa/mV
	820 feet	Hydrophone	96,000 S/s	2.8989×10^7 μPa/mV
	1,500 feet	Hydrophone	96,000 S/s	3.1199×10^7 μPa/mV
	4,000 feet	Hydrophone	96,000 S/s	2.8319×10^7 μPa/mV

5.2.9.2. DATA CAPTURE

For far field measurements at 500 feet, data were recorded directly into high speed recorders sampling at 2,000,000 samples/second. Also at 500 feet, signals were captured by a Roland solid state audio recorder sampling at 96,000 samples/second. At the other distances, the signals were captured by the Roland solid state recorders. The analog signals from these recordings were played back into the high speed recorder and sampled at 200,000 samples/second. Because the playback signals were analog, not digital, they were sampled at a rate twice the playback rate to be certain that the fluctuations were captured properly.

Dash 8HF-HS High Speed Recorder. At 500 feet in the east and south directions, a Reson TC4013 hydrophone and a PCB 138 transducer measured underwater data that was recorded in a Dash 8HF-HS high speed recorder at a rate of 2,000,000 S/s. Data from both transducers were recorded in voltage units, and two voltage ranges were used for both transducer types. For the hydrophone, input ranges on the Dash recorder were set to 1 and 10 Volts (V), while the input ranges for the PCB transducer were set to 0.1 and 1 V. This was done to ensure that the peak pressures were captured with both transducer types. The Dash recorder was programmed to trigger automatically when the hydrophone signal measured 0.05 V. Data was collected for eight seconds, with 800 milliseconds being pre-trigger data so the entire blasting event was recorded.

Roland R-05 Solid State Recorder. Each far field measurement location included a medium speed Roland R-05 solid state recorder with a maximum sampling rate of 96,000 S/s. At each location, either a Reson TC4013 or a Reson TC4033 hydrophone measured underwater data that was recorded with a Roland solid state recorder. At the unattended locations (i.e., 500, 820, and 4,000 feet), the Roland devices started recording at the time the hydrophone was deployed and continued for up to 14 hours until the equipment was collected following the blasting event. At the attended locations at 1,500 feet, the recorders were manually started prior to the blast and stopped following the blast. During post-processing, the audio recordings from the solid state devices were played into the Dash 8HF-HS high speed recorder so analysis of the voltage outputs could be consistent for all far field measurement locations. The Dash high speed recorder was programmed to record voltage at a sampling rate of 200,000 S/s; however, the hydrophone audio recordings would remain limited to the maximum sampling rate of the Roland solid state recorder (96,000 S/s).

5.2.10. Data Analysis

The near field data pressure signals were acquired and analyzed by Contract Drilling & Blasting LLC (CDB) under the direction of Albert VanNiekerk, Ph.D. and Aimone-Martin Associates LLC (AMA) under the direction of Dr. Cathy Aimone-Martin. The Far Field data was acquired by Illingworth & Rodkin, Inc. under the direction of Paul Donavan, Sc.D. As part of the quality assurance and quality control process, both teams exchanged raw data and analyzed the other’s results with their data analysis procedures. This resulted in consistent methods being applied through both data sets.

To compare with appropriate marine mammal and fish sound criteria, the implosion’s pressure signals were reduced and analyzed to obtain peak pressure level, impulse, cSEL, and RMS levels. The PCB transducers used at each near field location and at the 500-foot far field locations were designed to capture the true peaks in signals with rapid rise times, and as such, have excessive instrumentation noise. To eliminate this noise, each PCB signal was filtered using a low pass filter to reduce the high frequency content not because of the blasting event. Based on the signal, acoustic cutoff frequencies used for the near field analysis ranged from 8,000 to 50,000 Hz. The 500-foot signals were filtered with a cutoff frequency of 50,000 Hz. The hydrophone signals did not contain the high frequency noise found with the PCB transducers and did not require filtering.

Spreadsheet Calculations. The high speed recordings (1,000,000 to 2,000,000 S/s) from the near field and 500-foot far field locations were programmed to record up to eight seconds of data during the implosion event. The near field time signatures were provided in pressure units of psi in text format. The sampling rate of 1,000,000 S/s translated to approximately 8 million lines of data at each location. The high speed far field time signatures were exported in voltage units from the Dash 8HF-HS device in text format, as well, with 16 million total lines for both 500-foot locations. After the medium speed recordings (96,000 S/s) at the far field locations were scanned to isolate the implosion and captured in the Dash device, the time signatures were also exported in voltage units to text format. With the Dash device programmed to record at 200,000 S/s, the data set for each far field location totaled 1.6 million lines. All text files were imported into Microsoft Excel and converted into μPa using either 6.89×10^9 μPa/psi for near field measurements or the corresponding sensitivities shown in Table 10 for each far field location.

The pressure versus time signals from the near field and far field monitoring locations were processed using the same algorithm to calculate the required metrics. The peak pressure levels were determined by identifying the maximum pressure in each signal and calculating the level as defined in Equation 1. For the PCB transducers, the other quantities, as defined in Equations 2 through 8, were calculated using the numerical equivalent of these equations.

Real-Time Analyzer Calculations. For signals captured with at 96,000 samples/second, a Larson-Davis 3000 real-time analyzer (RTA) was used for some of the data processing. This instrument can be directly calibrated from the calibration signals recorded using the Roland solid state recorders and offers an improved dynamic range as the signals can be amplified on playback. However, the sampling rate of the RTA is limited as it is designed for the frequency range of human audibility. The RTA can directly capture and report the cSEL value or, alternatively, it can report the average of the sound pressure level over a time interval of 2.5 milliseconds. These average levels can also be summed using Equation 5 to calculate. Both methods give identical results. As a result, the RTA can be effectively used for determining cSEL values. This was verified by comparison to cSEL values determined for the 500 feet hydrophone data recorded with both the high speed and the Roland recorders. For the high speed recorder, the cSEL values were calculated with the spreadsheet method described above and then compared to those from the RTA. These compared to each other within 0.1 and 0.2 dB. As a result, the reported SEL $_{cum}$values were determined using the RTA. This method also provides the opportunity to examine the frequency content in the acoustic frequency range from 25 to 20,000 Hz.

5.3. Caged Fish Study

To assess the potential effects of the blast on fish in the Bay, the Department opted to conduct a Caged Fish Immediate Mortality and Injury Study (CFIMIS; Caged Fish Study). Details of the cage design and construction and fish species used can be found in the CFIMIS Study Plan (Caltrans 2015e) and are not repeated here. There were minor changes to the location of some of the cages following the October 31 test and in response to comments received from regulatory agencies up to close to the day of the Blast. The largest change was in the location of the cages. Cages were not deployed at distances of 100 and 125 feet, as called for in the CFIMIS Study Plan, because these locations were both within the turbulence created by the bubble curtain. These cages were deployed at 2,500 feet and 3,315 feet from Pier E3. The CFIMIS involved deployment of caged fish along a line extending out into the Bay from Pier E3. Cages were positioned along a surface poly rope line with buoys at 150, 200, 250, 350, 400, 500, 600, 700, 820 feet due south of Pier E3. Cages also were deployed from anchored boats at 2,500, and 3,315 feet from the pier face. Distances were closely matched to hydrophone locations. The caged fish buoy line was held in place by a crown buoy at each end, connected to a 2,500 pound deadman on the bottom. Late fall-run juvenile Chinook salmon approximately 5 to 8 inches in length were used as test subjects. Fish were transported from Coleman National Fish Hatchery and were acclimated to Bay water in a net pen within Clipper Cove, 2 days before the implosion. Pre-loaded cages containing approximately 40 fish were deployed about 1.5 hours before the implosion. Immediately following the implosion, the cages were retrieved and transported back to Clipper Cove to be processed. One additional cage was used as a control and was handled in exactly the same manner as the deployed cages, but was retrieved from the Bay prior to the implosion and was retained aboard the boat to avoid exposure to the pressure and sound waves.

Each cage was inspected by two fishery biologists back at Clipper Cove. Test fish were assessed as normal, impaired (unable to hold position in the water column, were swimming erratically or were lying on the bottom of the cage), or dead (no evidence of gill movement). All dead and impaired fish were removed from the cages and were necropsied following the implosion using a pre-established protocol to score external and internal injury. A subsample of 12 normal fish each from Cage 150, Cage 200, the Control Cage and 12 fish from the non-deployed net pen control fish were also necropsied. Each cage then had an associated number of normal, impaired and/or dead fish relative to distance from Pier E3. All necropsied fish were scored for external and internal injuries. All remaining live fish in each cage, which were classified as normal, were tallied and then were released into the net pen.

5.3.1. Sonar Assessment and Trawl Sampling

The Department was issued ITP Major Amendment No. 4 by CDFW (ITP No. 2081-2001-021-03, issued August 12, 2015) to include the authorized incidental take of listed species during the Demonstration Project. The ITP includes coverage of the Pier E3 implosion activities and augments existing monitoring and mitigation requirements. Per Section 3 (i) of the ITP, the Department was required to deploy sonar technology pre-implosion to establish a background of fish assemblages in the area. In addition, Section 3 (ii) stipulates that the Department was to conduct a series of oblique (mid-water) and otter (deep water) trawls to assess potential project related mortality and perform necropsies to help determine the cause of death. The following sections summarize the findings from these activities.

5.3.1.1. SONAR ASSESSMENT

To gain an understanding of fish distribution and assemblages present in the water column surrounding Pier E3, the Department conducted a series of sonar surveys before the implosion. The abundance and size of fish in the vicinity of Bay Bridge Pier E3 were estimated using mobile hydroacoustic survey techniques (Brandt 1996; Rudstam et al. 2009; Simmonds and MacLennan 2005). Hydroacoustic sampling was performed on 29 and 30 October 2015 along four transects in areas north and south of Pier E3. The surveys established the defined trawling areas north and south of Pier E3. In addition to surveying the trawling area for debris that could possibly snag the trawls, the locations of individual fish and large fish assemblages (schools) were recorded.

Sampling was conducted using a 70-kHz Simrad EK60 echosounder (Kongsberg Maritime AS, Norway) with a 7.1° split-beam transducer. The transducer was mounted downward-looking from a pole attached to the starboard side of the vessel and 0.5 m below the surface. During data collection, the echosounder transmitted ten pings per second with a pulse duration of 0.128 millisecond (ms). This pulse duration provided a vertical resolution between individual echoes of approximately 10 cm. Latitude and longitude coordinates were embedded directly into the raw acoustic files using the time-stamped National Marine Electronics Association (NMEA) output from a handheld GPS unit (Magellan eXplorist 310). The GPS unit was also used to maintain a vessel speed of 3 to 4.5 knots during data collection.

The echosounder system was calibrated in the field on 30 October using the standard target method (Foote et al. 1987) with a 38.1 mm tungsten-carbide sphere as the reference target. The target was suspended from a monofilament fishing line at a depth of approximately 8 m until echoes were detected throughout the beam and in the center of the beam (on axis). Gain levels were adjusted until measured target strength (TS) was equal to the theoretical TS of the reference target and then applied to the raw data during post-processing.

5.3.1.2. PRE-IMPLOSION TRAWLING

The Department used three trawling boats, two that were set up to tow otter trawls for sampling benthic (bottom-dwelling species) and one vessel set up to conduct oblique (mid-water) trawl for pelagic (open-water species).

Otter trawls were conducted from two 17 foot Boston Whalers. Each vessel towed an otter trawl with a 16 foot headrope and 1 inch stretch mesh body and 0.5” woven mesh cod end, with trawl doors that held the net open on the bottom to catch fish. Nets were deployed with a 5:1 scope in 40-50 feet of water depth and were towed on the bottom for

5 minutes per trawl at a speed of 1.5-2 knots, before being manually retrieved. After completion of each trawl, the contents of the catch were placed immediately into large tubs containing seawater and the boat was positioned for the next tow. While the net was redeployed for the next tow, two people recorded, identified, and enumerated the fish caught and separated the individuals into groups that were alive, dead, or moribund. Tows were conducted sequentially with approximately 10 minutes between net retrieval and redeployment at the next trawling location.

The midwater trawls were conducted off the R/V John Martin, which is a 56-foot oceanographic and research vessel with an A-frame, winch, sonar, fluorometer, and underway data acquisition system. The net had a 42-foot headrope and a 35-foot footrope, with 1” stretch mesh throughout, grading to 3/8” at the cod end, with doors that were sufficient to keep the net mouth open during towing. Midwater tows were conducted as oblique trawl tows (with the net deployed from the surface to the bottom and back up to the surface) and each tow lasted 10 minutes at a speed of 1.5-2 knots using a 3:1 scope. After completion of each trawl, the contents of the catch were placed immediately into large tubs containing seawater and the boat was positioned for the next tow. While the net was redeployed for the next tow, two people recorded, identified, and enumerated the fish caught and separated the individuals into groups that were alive, dead, or moribund. Tows were conducted sequentially with approximately 10 minutes between net retrieval and redeployment at the next trawling location.

The midwater and one otter trawler sampled north of Pier E3 and one otter trawl sampled on the south side of Pier E3 (Figure 33).

5.3.1.3. POST-IMPLOSION TRAWLING

The Department used same three trawling boats, net rigs and stationing as for the pre-implosion sampling. The sampling boats remained stationed outside the 1,500-foot Marine Traffic Safety Zone (MTSZ), and then began trawling within the designated areas north and south of the pier immediately following the implosion.

5.3.1.4. TRAWLING LOCATIONS

Trawling was conducted within the two previously identified trawling areas, located north and south of Pier E3. The two trawling areas were located between approximately 2,500 and 4,000 feet from Pier E3 (corresponding to the modeled distances of the 187 dB and 183 dB sound level thresholds for injury to fish). One area was located north of Pier E3 and one area was located south of Pier E3. An overview of the trawling zones is shown in Figure 33. Measured sound pressure levels, however, show the 187 dB cSEL and 183 dB cSEL thresholds were at distances of 899 feet and 1,230 feet from Pier E3,

Figure 33. Fishery Assessment Areas for Acoustic Surveys on October 29 and 30 and Trawl Tracks on October 31

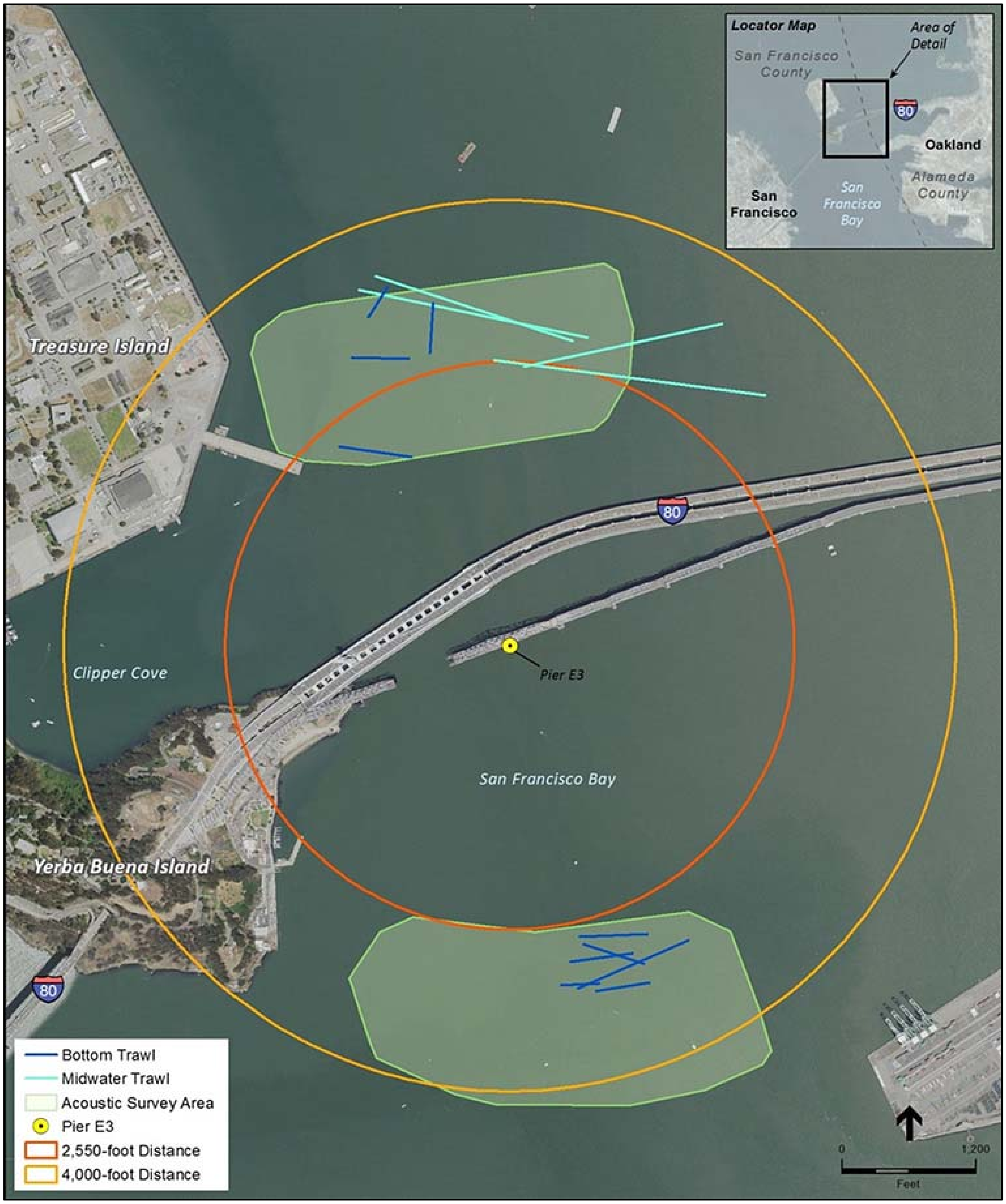


Figure 34. Fishery Assessment Areas for Acoustic Surveys on October 29 and 30 and Trawl Tracks on November 14

respectively. Therefore, fish potentially exposed to these sound levels would not have been captured in the trawls unless due to time and currents exposed fish had moved into the trawling area.

5.3.1.5. Trawling Duration

Recognizing that tidal currents in the project area could shift quickly and become strong, the Department and CDFW had an understanding that a short window existed surrounding the slack tide, when low-speed current conditions occurred. Therefore, trawling was conducted between slack tide (or the implosion) up to approximately 1 hour following the slack tide or the implosion. The trawling lasted approximately 70 minutes.

5.3.1.6. Fish Processing

For each trawl, a record was kept of species and a count for all fish, distinguishing between live, dead, and moribund fish. Moribund fish were identified by an inability to maintain an upright orientation, particularly when the water was “swirled” in the tub or new water was added. Live fish were identified by an ability to remain oriented in an upright position. Live fish were identified, counted, and then were released immediately back into the Bay. All fish of 7.8 inches fork-length or greater were measured before release. After all live fish were returned to the Bay, dead and moribund fish were counted, recorded, and then were returned to the Bay. Permit conditions required that any collected and dead or moribund federally or State-protected species: salmonids, Longfin Smelt, or Green Sturgeon, be retained and turned over their respective agencies, however none of these fish species were collected. For non-listed species, up to 10 representative individual fish per species were retained from each tow.

5.3.1.7. Necropsies

All fish retained from the trawl catches were preserved in 10 percent formalin for necropsies, to assess external and internal damage. All retained fish were labeled “Bay Bridge Implosion,” with the following information:

- Trawl type (otter trawl or oblique trawl)
- Date and tow start time (i.e., when net reached full scope),
- GPS coordinates of both the start and stop locations of the trawl
- Tow lane (1, 2, or 3)
- Tow number
- Species
- Length
- Disposition

- Preservative
- Name of collector

Necropsies were conducted by qualified fisheries experts, to assess the effects of both the sound and pressure waves on individual fish. Qualified individuals (with experience and knowledge of fish morphology, including internal organ position, shape, color and condition) assessed the fish for disease, parasite loads, general physical health, and injury. In addition to the assessment of physiological damage, all individual fish specimens retained were examined to confirm whether the injury/death resulted from the implosion or from the trawling, handling, or another cause.

5.3.2. Bird Predation Monitoring

Bird predation is defined as birds attempting to prey or feed on other organisms. Monitoring of predation activity consisted of counting bird strikes on the water surface. A bird strike on the water surface was not counted as a fish kill or fish consumption. Monitoring for bird predation was conducted in compliance with the terms and conditions of NMFS 2015 supplemental BO for the project, and the Department's Pier E3 Demonstration Project Biological Monitoring Programs. The purpose of the monitoring was to observe and record any occurrence of birds exhibiting predation behavior following the implosion of Pier E3. A congregation of birds striking the surface of the water was assumed to be evidence of some level of fish mortality and/or injury because of the underwater pressure wave generated by the implosion. However, monitoring or counting bird strikes on the water surface does not provide a quantifiable level of the magnitude of fish mortality. The monitors attempted to identify the species and size of any affected fish through observation with binoculars and collect any fish found floating at the water surface.

During the implosion work, one monitor tasked with recording bird strike data was positioned on the bike path of the new eastern span of the Bay Bridge in a location that afforded a clear view of Pier E3 and waters surrounding the pier. A boat with three monitors was staged approximately 1,500 south of the pier prior to the implosion, and was equipped with multiple nets and containers for storing collected fish. Of the three monitors on the boat, one was dedicated to collected bird strike data, while the other two were responsible for identifying and capturing impaired fish from the water. The boat was allowed into the blast zone approximately 15 minutes following the blast.

In addition to the dedicated bird monitors there were other members of the entire team that made observations.

5.4. Bird Monitoring

Bird monitoring was conducted immediately before, during, and following the implosion of Pier E3 in compliance with the Department's SFOBB Project Pier E3 Demonstration Project Biological Monitoring Programs (October 2015). As explained in Chapter 4, the Department utilized avian deterrence measures and established a 500-foot Avian Watch Zone to protect diving birds during the implosion of Pier E3. Because of sound's impedance at the air-water interface, it was concluded that impacts on birds would be limited to any individuals submerged in this 500-foot zone during the implosion. The following sections describe the avian monitoring that was conducted before, during, and after the Pier E3 implosion. Protected diving bird species include the California least tern and the California brown pelican.

5.4.1. Establishment of the Avian Watch Zone

To protect diving birds, the Department established a 500-foot Avian Watch Zone around Pier E3 prior to the implosion. This 500-foot zone reflects the modeled distance to a cSEL of 202 dB during the implosion (see Figure 35). In 2014, the Washington Department of Transportation and USFWS established a regulatory threshold of 202 dB cSEL for auditory injury and 208 dB cSEL for non-auditory injury thresholds during in-water pile driving for marbled murrelets (WSDOT 2014). Use of the auditory injury threshold (i.e., 202 dB cSEL) to avoid impacts on protected diving birds during the Pier E3 implosion was designed to maintain consistency with past projects where measures were taken to protected avian species.

5.4.2. Avian Deterrents

The Department used a combination of visual deterrents and hazing to encourage target avian species to relocate from the 500-foot Avian Watch Zone prior to implementation of the 1,500-foot MTSZ. A high-powered laser beam, operated by the avian monitor stationed on the bicycle and pedestrian pathway on the new east span, was used to visually deter birds. Per the Pier E3 Demonstration Project Biological Monitoring Programs, the avian monitoring boat was to haze birds in the area immediately outside the 500-foot Avian Watch Zone before the implementation of the MTSZ. However, on the morning of the implosion, birds were not observed in this area prior to the implementation of the MTSZ, and hazing was not necessary. The bird monitoring boat staged 1,500 feet south of Pier E3 following implementation of the MTSZ to conduct visual monitoring of birds in the vicinity of the Avian Watch Zone.

Propane-powered sound cannons were used to deter birds from the Avian Watch Zone immediately prior to the implosion. Propane-powered sound cannons emit a short, loud

Figure 35. Avian Watch Zone and Monitoring Locations

shot and can cover areas up to 5 acres. These sound cannons were staged on the barges supporting the air compressors for the Blast Attenuation System, located approximately 100 feet from Pier E3. The cannons were remotely triggered immediately prior to the blast to discourage individuals from occupying the Avian Watch Zone. Cannon fire immediately prior to the implosion ensured protected diving birds were cleared of the Avian Watch Zone and did not enter the water at the moment of implosion.

5.4.3. Avian Monitoring Plan

Avian monitors were located on the bicycle and pedestrian path of the new east span and on a boat to the south of Pier E3. Monitors observed and recorded all bird activity within the Avian Watch Zone for bird activity prior to, during, and following the implosion of Pier E3. The monitor in the bicycle and pedestrian path of the new east span was designated as the lead avian monitor and communicated directly with the Lead Biological Monitor. The following data was recorded:

- start and end time;
- monitoring location;
- time of observation;
- species and approximate number;
- location of bird observed;
- activity observed (e.g., flying through, foraging from the air, on water, diving, foraging below surface)

Per the Pier E3 SFOBB Project Pier E3 Demonstration Project Biological Monitoring Programs, if a protected (e.g., FESA, CESA, or CFGC-fully protected) bird(s) was sighted, the monitors would observe its activity. If the bird(s) was in the air and traveling from the watch zone, no further action would be necessary. If the bird(s) was sighted diving into or foraging in the water column within the 500-foot watch zone, the monitor would communicate this information to the lead avian monitor, who would then relay the information to the Lead Biological Monitor. The implosion of Pier E3 would be delayed until the protected species is no longer submerged in the water column within the watch zone. Departure of an individual bird from the Avian Watch Zone would be documented immediately and would be communicated to the Lead Biological Monitor.

If an injured or dead bird was sighted after the demolition blast event, the lead avian monitor would notify the Lead Biological Monitor who will contact USFWS and CDFW within 24 hours. Rescued or salvaged individuals would be transferred to a wildlife care facility for rehabilitation and will be released or euthanized if required. USFWS and

CDFW would have the authority to perform a necropsy on any captured bird to determine whether the implosion was cause of the injury or death. In addition to the protocol above, the following steps were followed prior to and/or during the implosion:

- The avian monitoring plan was finalized in coordination with the licensed blaster, the observation team, USFWS, CDFW, and the Department.
- The avian monitoring crew consisted of a lead avian monitor located on the bicycle and pedestrian path of the new east span, and three avian monitors staged in a boat to the south of Pier E3. All observers had previous experience in observing/spotting diving birds.
- Avian monitoring began at least 1 hour before the scheduled start of the implosion to identify the possible presence of diving birds. Monitoring during this period before the implosion allowed observers to evaluate the potential risk to protected species. Avian monitoring continued for 60 minutes after the implosion.
- Observers followed the protocol established in the October 2015 SFOBB Project Pier E3 Demonstration Project Biological Monitoring Programs and conducted the watch in good faith and to the best of their abilities.
- Per the October 2015 SFOBB Project Pier E3 Demonstration Project Biological Monitoring Programs, avian deterrents were used prior to the implosion.
- The implosion was weather-dependent. Climatic conditions had to be suitable for viewing of avian species. The implosion would have been delayed if weather conditions result in unsafe boat observations because of fog, wind, or heavy rain. The lead avian monitor, with direction from the Lead Biological Monitor, was to determine whether observation conditions were suitable before the start of the survey for the implosion.
- Implosion was limited to daylight hours for safety reasons and to allow for adequate observation of the project area for diving birds.

5.5. Marine Mammal Monitoring

5.5.1. Establishment of Marine Mammal Exclusion and Behavioral Response Zones

Before the implosion of Pier E3, a 1,160-foot (354 meter) Pacific harbor seal and California sea lion exclusion zone (see footnote in Table 11), a 5,700-foot (1,737 meter) northern elephant seal exclusion zone, and a 26,500-foot (8,077 meter) harbor porpoise exclusion zone was established (Table 11). The Marine Mammal Exclusion Zones (MMEZs) included all areas where the underwater SPLs or SELs were anticipated to equal or exceed the Level A threshold criteria for harbor seal and the TTS criteria for sea lion, elephant seal, and harbor porpoise.

A 5,700-foot (1,737 meter) Level B Harassment—TTS monitoring zone was established for harbor seals (Table 11). A 9,700-foot (2,957 meter) Level B Harassment—Behavioral Response monitoring zone was established for pinnipeds (i.e., harbor seal, sea lion, and elephant seal) (Table 11). A 44,500-foot (13,564 meter) Level B Harassment—Behavioral Response monitoring zone was established for harbor porpoise (Table 11).

Table 11. Exclusion and Monitoring Zones

<table>
<tr><th rowspan="2">Species</th><th rowspan="2">Exclusion Zone</th><th colspan="2">Monitoring Zone</th></tr>
<tr><th>TTS</th><th>Behavioral Response</th></tr>
<tr><td>Pacific harbor seal</td><td>1,160 feet
(354 meters)</td><td>5,700 feet
(1,737 m)</td><td>9,700 feet
(2,957 meters)</td></tr>
<tr><td>California sea lion*</td><td>1,160 feet
(354 meters)</td><td rowspan="3">No TTS take was allowed. Area was included in Exclusion Zone</td><td>9,700 feet
(2,957 meters)</td></tr>
<tr><td>Northern elephant seal</td><td>5,700 feet
(1,737 meters)</td><td>9,700 feet
(2,957 meters)</td></tr>
<tr><td>Harbor porpoise</td><td>26,500 feet
(8,077 meters)</td><td>44,500 feet
(13,564 meters)</td></tr>
</table>

Note:
The IHA required a 470-foot (143 meter) exclusion zone and an 800-foot (244 meter) Level B Harassment—Behavioral Response monitoring zone for California sea lion. As these zones are in the near-field of the implosion, the Department elected to monitor a larger exclusion zone and Level B Harassment—Behavioral Response monitoring zone for this species.
Source: NMFS 2015

5.5.2. Marine Mammal Observers

A minimum of 10 NMFS-approved marine mammal observers (MMOs) were required by the IHA during the Pier E3 controlled implosion; however, the Department elected to employ a minimum of 13 MMOs so that all of the MMEZs, Level B Harassment—TTS and Behavioral Response zones were monitored. MMOs were positioned near the edge of each of the pinniped threshold criteria zones and within the larger harbor porpoise exclusion zone, using boats, barges, bridge piers, and roadway, as well as sites on YBI and Treasure Island. One MMO was designated as the lead MMO and located on the new bridge's bike path and was in constant communication with the Lead Biological Monitor who was physically with the Department Resident Engineer during the implosion. The lead MMO received updates from the other MMOs on the presence or absence of marine mammals within the MMEZs and notified the Lead Biological Monitor of cleared MMEZs before the implosion.

5.5.3. Monitoring Protocol

Implosion of Pier E3 was conducted when there was sufficient visibility to monitor for a minimum of 30 minutes prior to the implosion. The implosion occurred during good weather (i.e., clear skies and no high winds) so that the MMOs were able to detect marine mammals within the MMEZs and beyond. As the time for the implosion approached, any marine mammal sightings were discussed between the lead MMO, the Lead Biological Monitor and the Department Resident Engineer. If any marine mammals had entered the MMEZs within 30 minutes of blasting, the lead MMO would have notified the Lead Biological Monitor and Resident Engineer that the implosion may need to be delayed. The lead MMO would have kept them informed of the disposition of the animal. If the animal remained in the MMEZs, blasting would have been delayed until it had left the MMEZs. If the animal dove and was not seen again, blasting would have been delayed at least 30 minutes from the time the animal was last sighted. After the implosion occurred, the MMOs continued to monitor the area for at least 60 minutes.

Although any injury or mortality to marine mammals from the implosion of Pier E3 was very unlikely, boat and shore surveys were conducted for 3 days following the event to determine whether any injured or stranded marine mammals were in the area. If an injured or dead animal was discovered during these surveys or by other means, the NMFS-designated stranding team would be contacted to pick up the animal. Veterinarians would treat the animal or conduct a necropsy to attempt to determine whether it was stranded or injured by the Pier E3 implosion.

5.5.4. Data Collection

Each MMO recorded his/her observation position, start and end times of observations, and weather conditions (e.g., sunny/cloudy, wind speed, fog, visibility). For each marine mammal sighting, the following items were recorded, if possible:

1. Species
2. Number of animals (i.e., with or without pup/calf)
3. Age class (i.e., pup/calf, juvenile, adult)
4. Identifying marks or color (e.g., scars, red pelage, damaged dorsal fin)
5. Position relative to Pier E3 (i.e., distance and direction)
6. Movement (i.e., direction and relative speed)

7. Behavior (e.g., logging [resting at the surface], swimming, spy-hopping [raising above the water surface to view the area], foraging)
   [Signs of injury, stress, or other unusual behavior also will be noted.]

8. Duration of sighting or times of multiple sightings of the same individual

5.5.5. Communication

All MMOs were equipped with mobile phones and/or radios. One person was designated as the lead MMO and was in constant contact with the Lead Biological Monitor who was with the Department Resident Engineer. The lead MMO coordinated marine mammal sightings with the other MMOs. MMOs contacted the other MMOs when a sighting was made within the MMEZs or near the MMEZs so that the MMOs within overlapping areas of responsibility could continue to track the animal and the lead MMO was aware of the animal. If the sighting was within 30 minutes of blasting and an animal had entered the MMEZs or was near it, the lead MMO notified the Lead Biological Monitor and made updates on the animal's disposition and direction of travel.

5.5.6. Real-Time Acoustic Monitoring

Although harbor porpoises were not expected to be in the project area (within 44,500 feet [13,564 meters] of the Behavioral Response zone) in November, real-time acoustic monitoring to confirm species absence and active monitoring was performed by trained observers. Harbor porpoises vocalize frequently with other animals in their group, and they use echolocation to navigate and to locate prey. Therefore, real-time acoustic monitoring can be used to detect this species as a supplement to visual monitoring.

Harbor porpoise generally are observed near the entrance to the Bay between the Golden Gate Bridge, Tiburon, Angel Island, the north side of the west span of the Bay Bridge and west side of Treasure Island. Two bio-acousticians performed real-time acoustic monitoring within the 26,500-foot (8,077-meter)-radius harbor porpoise exclusion zone north of the east span of the SFOBB. An MMO was also present on the acoustic monitoring boat to perform visual monitoring. A high-frequency hydrophone, calibrated to detect harbor porpoise, was towed from the monitoring boat. All acoustic monitoring equipment was calibrated and tested before the implosion to check functionality.

Acoustic monitoring started just prior to sunrise on the morning of the implosion and continued through the implosion and for at least 60 minutes following the implosion. The acoustic monitoring boat transited slowly throughout the northern portion of the harbor porpoise exclusion zone, north of the east span of the SFOBB. Acoustic and visual monitoring efforts focused on deeper water areas north of Treasure Island, near the western edge of the harbor porpoise exclusion zone, because this is the most likely area of the exclusion zone to be visited by a transiting harbor porpoise. The acoustic monitoring equipment would not be able to give an accurate location for the detected animals but would provide a relative distance and direction so that the MMOs could search for the animals and determine whether those animals have entered or may enter the exclusion zone. If a harbor porpoise was detected either through audible "clicks" or visually before the implosion, the lead MMO would have been notified immediately. On detection of clicks, the acoustic monitoring boat would travel in the direction of the detected animal to confirm its location visually. If the animal was confirmed to be within the exclusion zone, the lead MMO would notify the Lead Biological Monitor, who would notify the Department Resident Engineer to delay the implosion. The animal would be tracked and after outside the exclusion zone, the implosion would proceed as planned. If the animal could not be visually located, the implosion would be delayed for 30 minutes after the last click was detected.

5.5.7. Acoustic Deterrent Devices

Acoustic deterrent devices (ADDs) commonly are used in commercial fishing and at fish farms to scare marine mammals away from nets or structures to prevent predation on fish, but they have not been used during blasting to minimize impacts. These devices supplemented the visual monitoring, to deter marine mammals from entering the MMEZs before and during the implosion. The pulse of the ADDs had a frequency of 10 kHz, at sound levels of approximately 130 dB with regular interpulse intervals of 4 seconds (Airmar manufacturing specifications). The Airmar ADDs had an effective range of approximately 300 feet (100 meters).

Marine mammals may habituate to ADDs over time, because nets or fish farms are a regular source of food. It is likely that marine mammals, particularly harbor seals that are resident to the Bay, have never encountered ADDs and therefore, the ADDs were an effective deterrent for the short time they were used before detonation (up to 2 days prior to the blast, for several hours each day). An ADD was attached to each demarcating buoys to deter seals or sea lions from the 1,160-foot (354-meter) Level A and mortality threshold areas. Two ADDs were suspended from Pier E2 of the new bridge, the closest structure to Pier E3 and a common foraging location for harbor seals. ADDs were also suspended from each boat carrying an MMO at the specified MMEZ, with the exception of the boat used for the real-time acoustic monitoring for harbor porpoise to prevent disruption to the hydroacoustic monitoring equipment.

5.5.8. Stranding Plan

A stranding plan was prepared, in cooperation with the NMFS-designated marine mammal stranding, rescue, and rehabilitation center for central California. Although avoidance and minimization measures were likely to prevent any injuries from the implosion, preparations were made in the unlikely event that marine mammals were injured. In addition, it would be necessary to determine the cause of stranding for any marine mammals that appear within 3 days after the implosion. Sick, injured, or dead marine mammals often strand in the Bay because of the large number of marine mammals, primarily pinnipeds, which inhabit or regularly use the Bay. Therefore, sick or injured individuals observed after the implosion would need to be examined more thoroughly to determine the cause of the stranding.

Elements of the stranding plan included the following:

1 A stranding center crew and a veterinarian was on call near the Pier E3 site at the time of the implosion to quickly recover any injured marine mammals, provide emergency veterinary care, stabilize the animal's condition, and transport individuals to the stranding facility. If an injured or dead animal was found, NMFS (both the regional office and headquarters) would have been notified immediately, even if the animal appeared to be sick or injured from a cause other than the implosion.

2 The stranding center crew would prepare treatment areas at the facility for cetaceans or pinnipeds that may be injured by the implosion. Preparation would include equipment to treat lung injuries, auditory testing equipment, dry and wet caged areas to hold animals, and operating rooms if surgical procedures were necessary. The stranding center regularly treats sick and injured marine mammals, so all of the facilities and equipment were ready at all times. Equipment to conduct auditory brainstem response hearing testing will be available to determine whether any inner ear threshold shifts (TTS or PTS) had occurred (Thorson et al. 1999).

3 Any veterinarian procedures, euthanasia, rehabilitation decisions and time of release or disposition of the animal would be at the discretion of the stranding center staff and the veterinarians treating the animals. Any necropsies to determine whether the injuries or death of an animal was the result of the implosion or other anthropogenic or natural causes would be conducted at the stranding center by the crew and veterinarians. The results would be communicated to the Department and NMFS as soon as possible, followed by a written report within a month.

4 Post-implosion surveys were conducted immediately after the event and over the following three days to determine whether any injured or perished marine mammals were in the area.

A stranding team from the Marine Mammal Center of Sausalito, California, consisted of a veterinarian and two volunteers. The team was stationed at a nearby berth on the morning of the implosion and was dispatched for a post-blast survey approximately 2 hours following the blast.

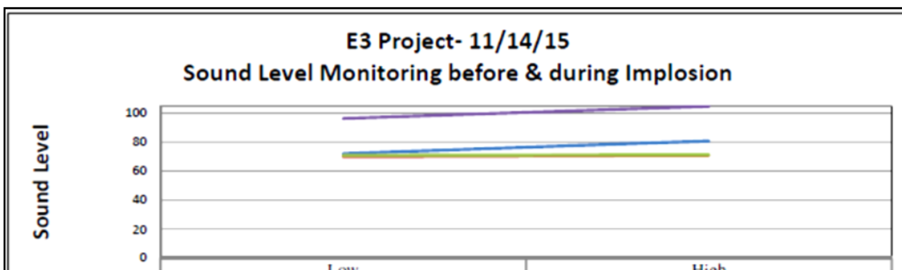
5.6. Airborne Noise Monitoring

Airborne noise monitors were stationed on the bike path of the self-anchored suspension span of the Bay Bridge approximately 500 feet (approximately 150 meters) from Pier E3 and approximately 180 feet (55 meters) above the bay water surface. The traffic on the adjacent bridge was 40 -170 feet (12 to 51 meters) from the monitors. Several key project personnel, including the blaster in charge, were located directly below this location on Pier E2 of the new bridge.

The blast was not loud enough to cause physical discomfort to anyone at either location and no one reported any discomfort with the level of noise produced by the demolition.

Hand held decibel meters were deployed by the monitor on the bike path above. The meters were in direct line of sight and significantly closer to the blast than traffic on the new bridge. Traffic was shielded from the noise by the new bridge and the vehicles they occupied. Recorded sound level readings are shown below in Table 12. The reading of light traffic prior to the blast varied between 72.2 dB and 81 dB. Readings during the actual sequenced implosion varied between 96.4 dB and 104.8 dB. Common environmental noises of this magnitude are experienced by the operator of a lawn mower, chainsaw, small motorcycle or snowmobile.

Table 12. Recorded sound levels.



	Low	High
Traffic Flow	72.2	81
Trafic Stop	70.01	71
Bird Canon	71	71.5
Blast	96.4	104.8

Chapter 6. Implosion Results and Impacts

6.1. Subsurface Sonar Scan

Hydrographic surveys of the bay floor in the vicinity of Pier E3 were performed several times including: prior to demolition, immediately after the controlled implosion of Pier E3, and after cleanup of blast related equipment and accessible concrete debris. The final surveys are shown in Figures 36 through 38. Each image shows the bathymetry of Pier E3 and the surrounding bay floor in elevations referenced to the National Geodetic Datum of 1929. In each image, elevations are represented by colors which transition as indicated on the legend strip on the right side, from red through green, to dark blue and black (shallow to deep). Five foot interval contour lines are included on the images to assist in reading the color transitions.

Survey Methods

Hydrographic surveys were conducted by boat using a multibeam sonar system and a global positioning system (GPS). Software packages were used to calibrate, collect, and process the survey datasets.

Surveys were conducted by eTrac Incorporated. The survey vessel "*S/V Taku*" was used for the data acquisition. An R2Sonic 2024 Multibeam Sonar was used to acquire sounding data. Positions were acquired using an Applanix POSMV Wavemaster GPS with combined inertial positioning and motion reference. The acquisition hardware was interfaced with a QPS Qinsy Multibeam software package. Sound velocity corrections were obtained with an AML sound velocity profiler and applied to the MBES data in real time.

Processing was performed using the QPS Qinsy and Qloud software packages and Hypack. Final images were created in Autocad Civil3D, Qloud and Global Mapper 16.0.

Post-implosion surveys were performed several times each day for multiple days leading up to the final survey of the area. Construction operations were directed with real-time acquisition and analysis of the data. Maximum coverage was targeted in an effort to ensonify all possible obstructions and structures in the area surveyed. Times of best GPS and GLONASS constellation geometry were planned to perform the highest under-structure accuracy survey work in the field. The Applanix POSMV inertial positioning system was used for under bridge data collection, which was attained even with decrease or loss of satellite coverage.

Passes were made by the survey vessel at slow, consistent speeds with minimum steering corrections following established perpendicular transects to allow the system to most effectively use the inertial inputs from the gyro to capture data.

Survey Results

Figure 36 shows the results of the pre-demolition survey conducted on August 7, 2015. This image shows the Pier E3 in place with buttress walls on two sides.

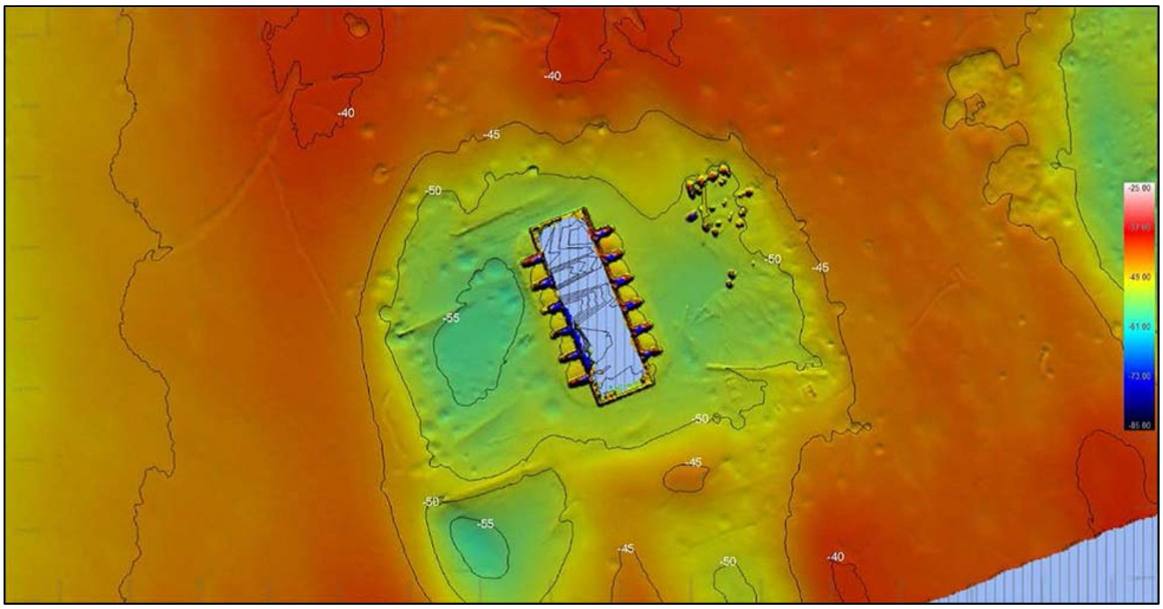


Figure 36. Pier E3 Pre-Implosion, August 7, 2015

Figure 37 shows the results of the post demolition survey conducted on November 14, 2015. This image shows the deep depression into which demolished Pier E3 collapsed after the implosion and the associated rubble and blast equipment that necessitated cleanup. A reddish orange area protruding above the -45 contour on the south end of the caisson was noted as an area that would require management. Other high spots occurred around the perimeter of the caisson. Some of these were portions of the corners of pier buttress walls that remained in place. These remnants ranged in height from approximately three to six feet and were mechanically removed during the final site cleanup.

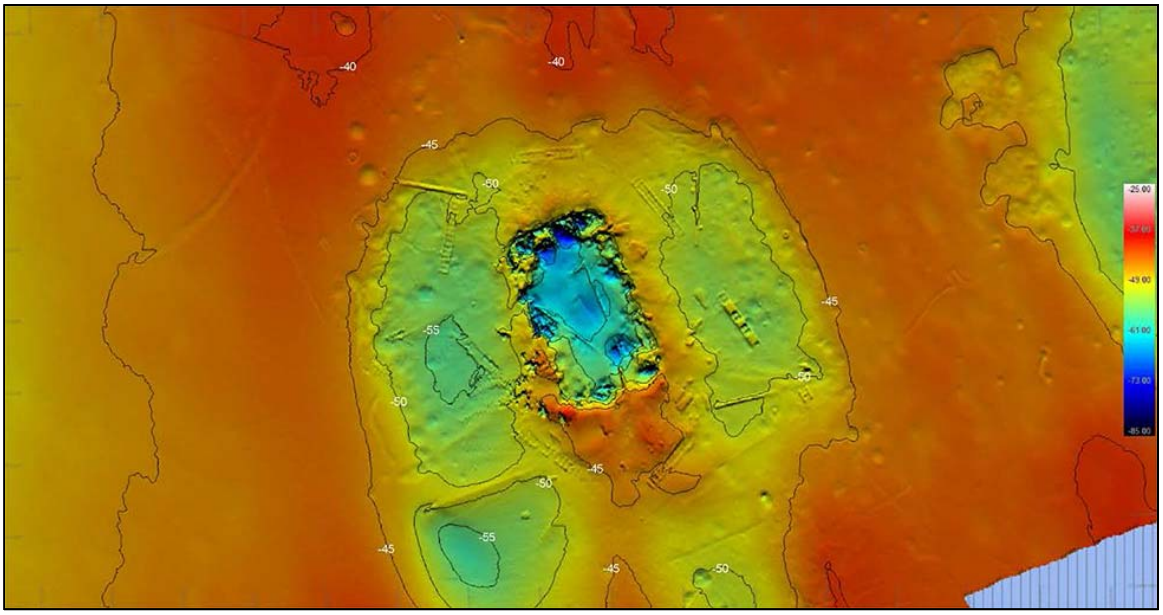


Figure 37. Pier E3 Site after Implosion, November 14, 2015

Figure 38 shows the results after the final clean up. This survey was conducted on December 10, 2015. This image shows the condition of the site after all blasting equipment had been retrieved. Several beams found near Pier E3, likely discarded during construction of the original east span in the 1930s, were moved out of the way of the BAS frames prior to the blast to the northwest and southeast of Pier E3 were removed pursuant to regulatory agency requirements. All concrete demolition was completed to below the pre-construction surrounding low scour line. The debris that fell outside the caisson was dredged up with a clamshell bucket and placed inside the caisson as planned. There are still pits that remain inside the caisson that extend to approximately 70 feet deep, as indicated by the green and dark blue areas on Image 3. Contours of the scoured area surrounding Pier E3 have been restored to a condition similar to the pre-demolition condition as planned. The scoured area around Pier E3 is anticipated to silt up to meet the elevation of the surrounding area to an approximate depth of less than 45 feet, burying the caisson remains to a depth of over five feet.

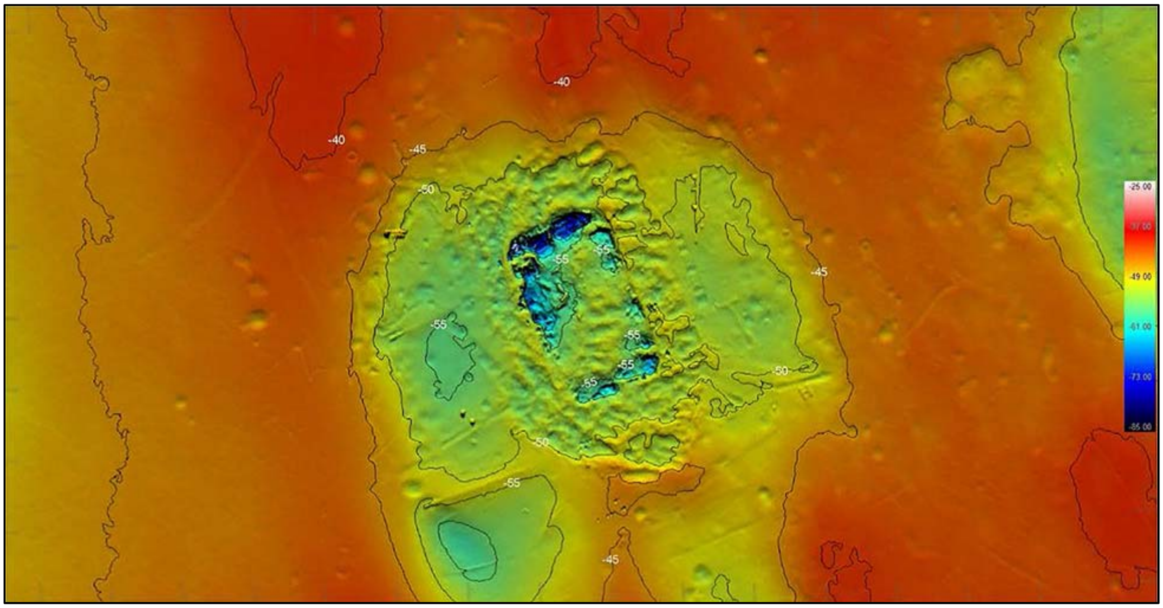


Figure 38. Pier E3 Site after Completion of Cleanup Activities, December 10, 2015

Debris Cleanup

Cleanup activities were initiated on November 14, 2015, immediately following the implosion of Pier E3. A post-blast hydrographic survey was conducted on November 14, 2014, to locate blast related equipment, assess the success of removal of the upper caisson of Pier E3 by implosion and to determine the amount of rubble that would need to be managed. The blast related equipment to be retrieved included the BAS frames, steel blast mats, steel cables, and I-beams. Divers were dispatched to confirm items identified in the hydrographic survey. Most implosion-related materials were removed from the Bay with a clamshell bucket mounted on a barge-based derrick crane.

The post-implosion hydrographic survey showed areas of the Pier E3 caisson that had significant void space, as well as areas where debris had mounded above the planned limits of demolition. In particular, the hydrographic survey results showed debris mounded at the southern edge of the caisson. The crane-mounted clamshell bucket was used to tamp down mounded debris and re-distribute it into the voids of the remaining lower caisson. Large debris that fell outside the caisson and onto the Bay floor were dredged up with the clamshell bucket and placed into the voids of the lower caisson.

Following the initial cleanup of the imploded remains of Pier E3, there were nine areas associated with the pier's remaining structure that protruded above the -51-foot removal limit. These included portions of six buttress walls, a portion of the caisson wall, a debris pile, and a rebar cluster. Similar to the operation above, a clamshell bucket was used to tamp down and dredge up protruding debris and re-distribute it into the voids of the remaining lower caisson.

All of the Pier E3 implosion cleanup activities were completed on December 10, 2015. Overall, approximately 13 percent of the rubble generated from the implosion of Pier E3 landed outside the footprint of the pier.

6.2. Hydroacoustic/Underwater Pressure Monitoring and BAS Effectiveness

6.2.1. Sound Pressure Level vs. Time

Sound pressures were measured at six near field positions: one along the east line at 23.5 feet; and five along the north line at 24.5, 74.5, 101, 126.5, and 153 feet (see Figure 30). Hydroacoustic data was taken at seven far field positions: three along the east line at 500, 820, and 1,500 feet; and four along the south line at 500, 820, 1,500, and 4,000 feet (see Figures 39 and 40). All of the monitoring was done at a depth of 20 feet. Figures 39 and 40 show the time histories for the far field measurement locations along the east and south lines, respectively. Because of the number of data points captured with the 2,000,000 S/s and 200,000 S/s sampling rates, the results shown in Figures 39 and 40 were sampled at 100,000 S/s. Comparison of the peak sound pressure levels calculated with the 200,000 S/s and 100,000 S/s sampling rates resulted in negligible differences no greater than 0.3 dB. Therefore, the time histories shown in the figures for far field locations at 820 feet and beyond would be identical for the 200,000 S/s. At 500 feet, the peak sound pressure level is lower than it would be with the 2,000,000 S/s sampling. The time for each figure is relative to the recordings and does not directly correlate to the timing of the blast event. Each recording was lined up starting at the time the first indication of the blast occurred.

In the east direction (Figure 39), the two highest peaks are located close together just prior to the one second mark occurring about 0.5 seconds after the initiation of the recording. These peak pressure levels were over 10 dB higher than any other peaks measured during the event. Aside from these two peaks, the other highest peaks in the first 4 seconds of the blast were typically between 190 and 199 dB. As noted in Table 3, the calculated peak sound pressure levels for the 588 individual charge weights cover a range of only about 2 dB relative to each other. The results shown in Figure 39 indicate that circumstances other than charge weight differences created the two high peak levels occurring around 0.5 seconds into the implosion event.

In the south direction (Figure 40), the highest peaks in the first two seconds are somewhat more consistent than in the east direction.

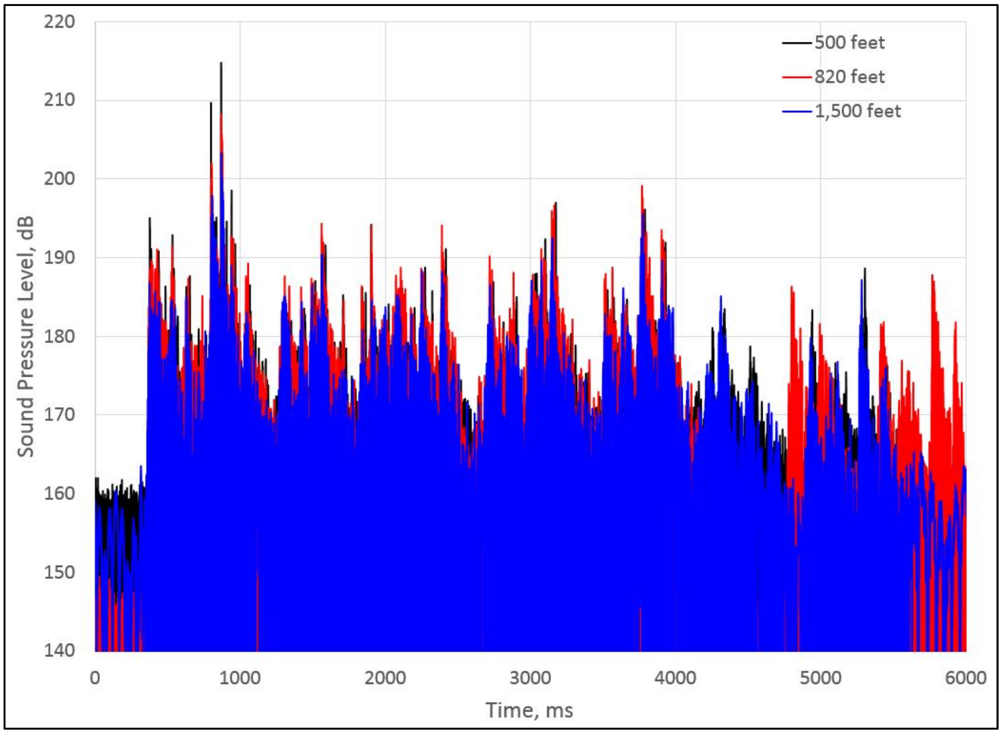
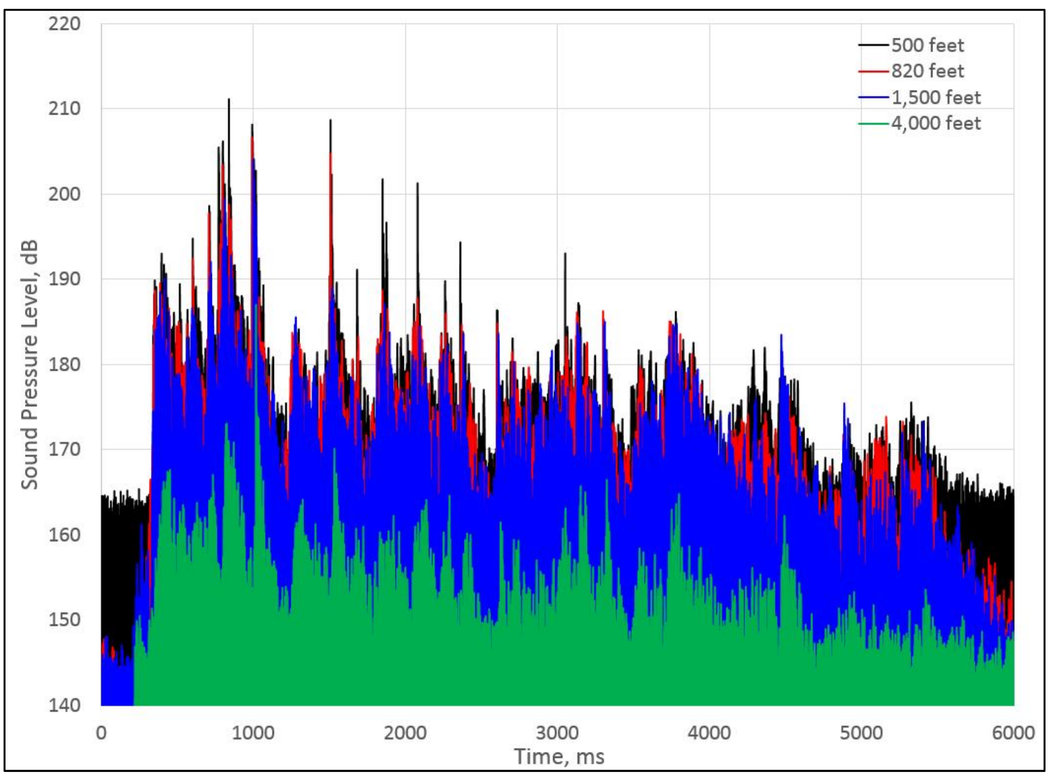


Figure 39. Far Field Time Histories along the East Line



Note:
Far field time histories along the south line at 500, 820, 1,500, and 4,000 feet, sampled at 100,000 S/s.

Figure 40. Far Field Time Histories along the South Line

From the highest peak occurring about 0.5 seconds into the event, the peaks tend to decrease in amplitude with time. For the blast plan, as shown in Figure 16, this is expected as the blasting moves south to north, and the distance from the blasts to the monitoring locations increases. For the east direction (Figure 39), the blasts continue down the length of the pier at a similar distance from the monitoring locations. For the south direction, it is particularly apparent that the "peaky-ness" of the sound pressure levels generally decreases with increased distance from the blasts. This can be seen by considering the peak that occurs at a time of approximately about 1,500 milliseconds, as shown in Figure 40. At the distances of 500 and 820 feet, the peak is much higher in level than the surrounding levels by about 20 dB. At 1,500 and 4,000 feet, this same peak is only about 10 dB greater than the surrounding levels. An interesting exception to this is the peak that occurs at the 1,000-millisecond grid line. In this case, the peak at 4,000 feet remains quite "sharp" and is about 20 dB higher than the surrounding data.

6.2.1.1. Cumulative SEL vs. Time

The cSEL was calculated numerically for the 2,000,000 S/s PCB in the near field and at 500 feet. In the far field and 500 feet, cSEL was determined using the RTA for the hydrophone data sampled at the rate of 96,000 S/s. At the overlapping positions at 500 feet, the cSEL determined with the pressure transducers and the hydrophones were within 2 dB of each other. Because the cSEL calculated numerically for the PCB and with the RTA for the hydrophone differed only by these small amounts at the 500 feet locations, it was determined that the energy accumulated over the entire blasting event was captured adequately with the slower sampling rate. Unlike peak sound pressure level, the cSEL values are not as sensitive to sampling rate at the closer monitoring locations.

Differences in the progression of the blasts noted for Figures 39 and 40 are also apparent in plots of the cSEL versus time. For the cSEL in the east direction, as shown in Figure 41, the two large peaks shown in Figure 39 have a major effect in determining the ultimate cSEL value for the 500-foot monitoring distance. These peaks define a rise in cSEL of about 12 dB in a short time, starting at about 1,600 milliseconds, as shown in Figure 41. After these two peaks, the cSEL versus time curve flattens, increasing only about 1.5 dB in the remainder of the implosion event. For the further distances, the rise is not as pronounced, and the cSEL continues to build over the duration of the event, increasing by about 3.5 dB and 4 dB for the 820 and 1,500 feet distances, respectively. For the 820 feet cSEL, the final value actually exceeds the 500-foot result, as the more uniform peaks after about 2,300 milliseconds continue to increase the accumulated cSEL. The effect of more uniform peaks is also seen at the 1,500-foot location, although the cSEL remains lower than the other two distances. The cSEL versus time in the south direction is shown in Figure 42. In this direction, the build-up of energy is slightly more gradual than in the east direction, as would be expected from Figures 39 and 40. Because of the general decrease in peak sound pressure level as the implosion progresses, there is little increase in cSEL after about the 2,000-millisecond mark. However, these data do indicate that the individual peak levels near the beginning of the event contribute to the cSEL during the buildup of energy more in a step-wise fashion occurring before the 1,500-millisecond mark. Unlike the east direction, the cSEL in the south direction determined at 500 feet was approximately 5 dB greater than the cSEL at 820 feet.

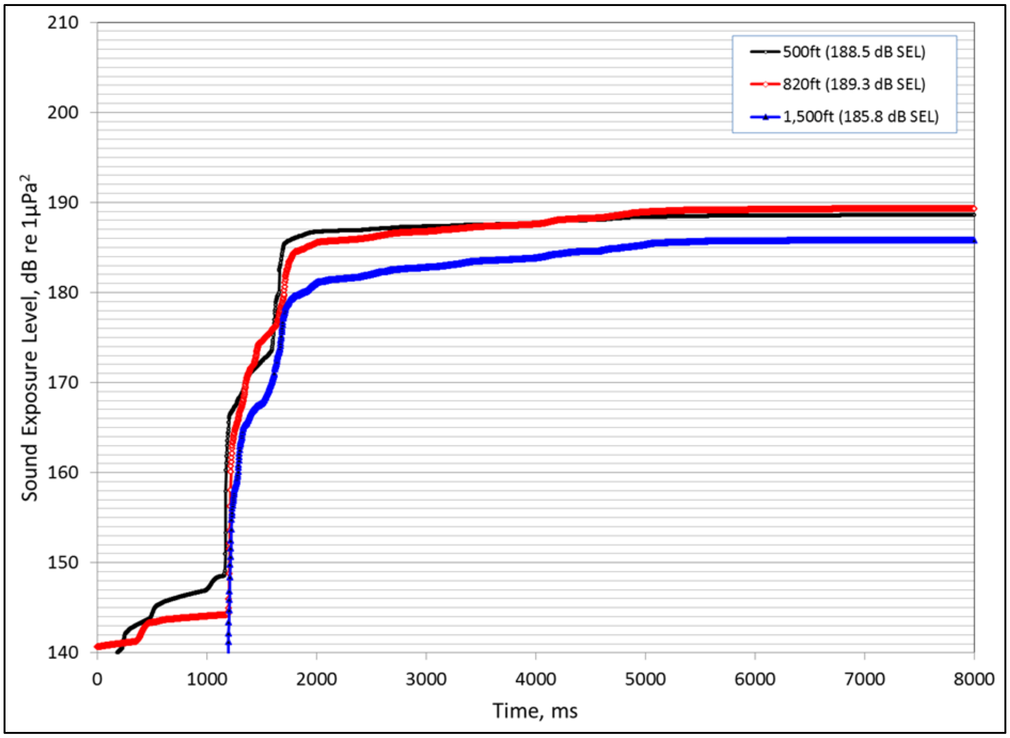


Figure 41. Far Field cSEL along the East Line at 500, 820, and 1,500 Feet

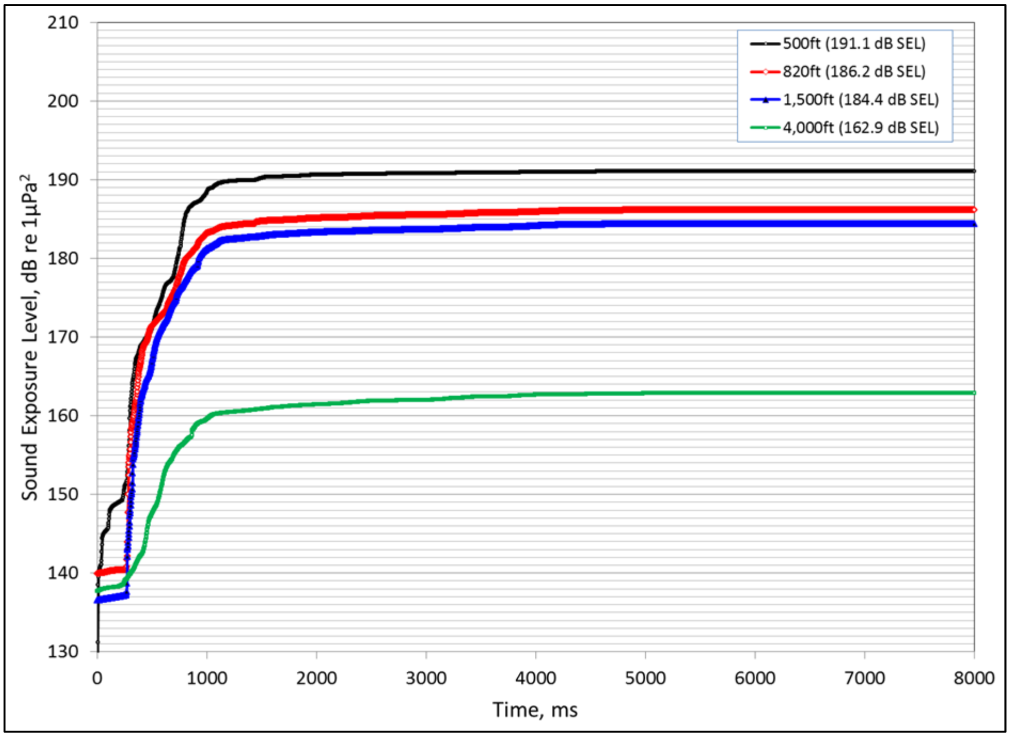


Figure 42. Far Field cSEL along the South Line at 500, 820, 1,500, and 4,000 Feet

The difference between the 820 and 1,500 feet cSEL was about the same in the east and south direction. Using the RTA, the frequency content of the cSEL can also be compared for the different distances and between the east and south directions. cSEL for the three distances in the east direction are compared in Figure 43 for one-third octave acoustic frequency bands from 25 to 20,000 Hz. For these data, the spectra for all three distances are dominated by the energy below 1,000 to 2,500 Hz acoustic frequency range. The lower acoustic frequency content is noted to increase with distance, implying that the higher frequency energy attenuates more rapidly with distance. A similar plot for the south direction is shown in Figure 44. For the 500, 820, and 1,500 feet distances, the spectra are again dominated by lower acoustic frequencies, less than about 3,150 Hz. The spectrum for the 4,000-foot position is more complex. For both directions, there is a noticeable dip in the 1,500-foot spectrum beginning at 1,250 Hz and extending higher to about 4,000 Hz. At 4,000 feet in the south direction, a dip is seen at even lower acoustic frequencies, from about 125 to 800 Hz, and another dip is apparent between 1,250 and 6,300 Hz. These behaviors may be because of interference effects created by the surface release wave discussed in conjunction with those shown in Figure 19.

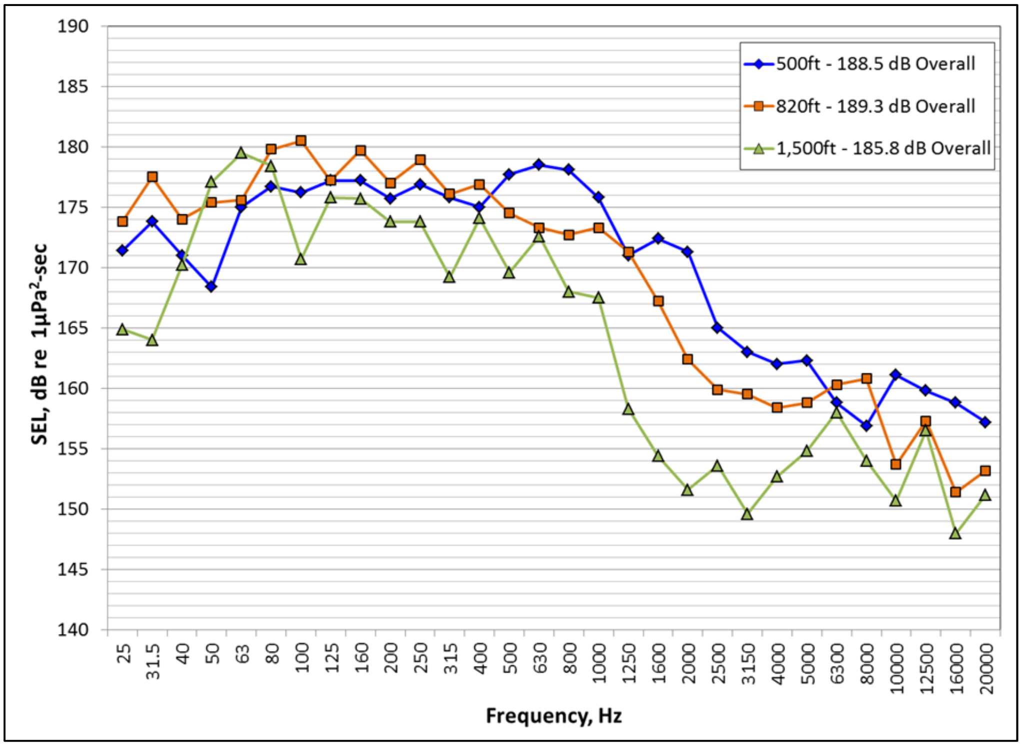


Figure 43. One-Third Octave band Levels for cSEL at the Far Field Monitoring Locations to the East

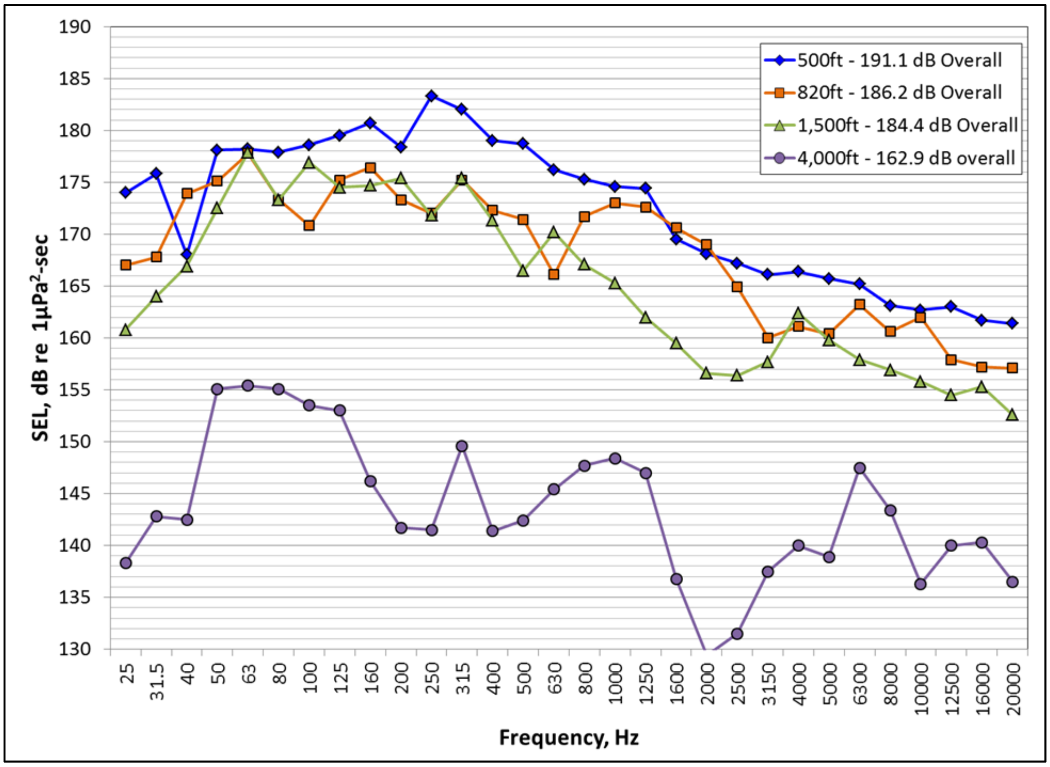


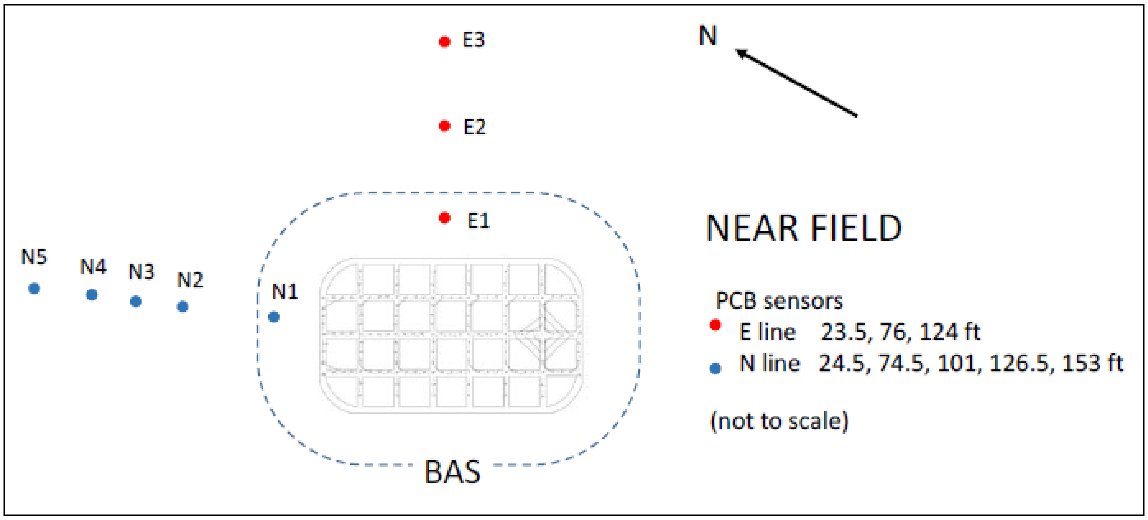
Figure 44. One-Third Octave Band Levels for cSEL at the Far Field Monitoring Locations to the South

6.2.2. Near Field Peak Pressures, Data Filtering and BAS Effectiveness

6.2.2.1. BLAST PRESSURE SENSOR FILTERING

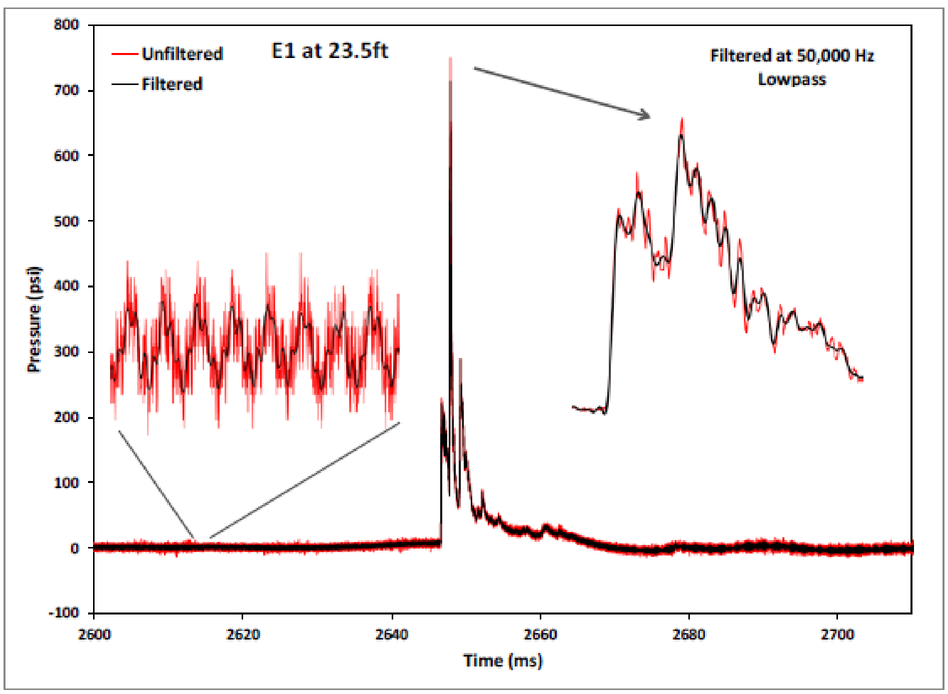
Near field data obtained was analyzed first to determine peak pressures, assess data quality, and evaluate the performance of the BAS. The PCB pressure sensors have an inherent amount of high-frequency electronic noise and hence the pressure records required post-process filtering. Careful consideration was given in selecting a low-pass filter to remove the high-frequency noise without removing key signatures of the true pressure amplitude.

For sensors inside the BAS (Figure 45) and outside the BAS, pressure shock fronts were steep and included a very fast rise in amplitude. As such, a higher frequency filter was selected. Figure 46 shows an example of this at location E1 where a 50,000 Hz low-pass filter was chosen. The background noise is shown on the left and is not completely removed by this filter frequency. The peak is enlarged on the right and shows that the sharp rise in pressure is maintained with this filter choice.



Note:
Distances from the pier are noted in feet.

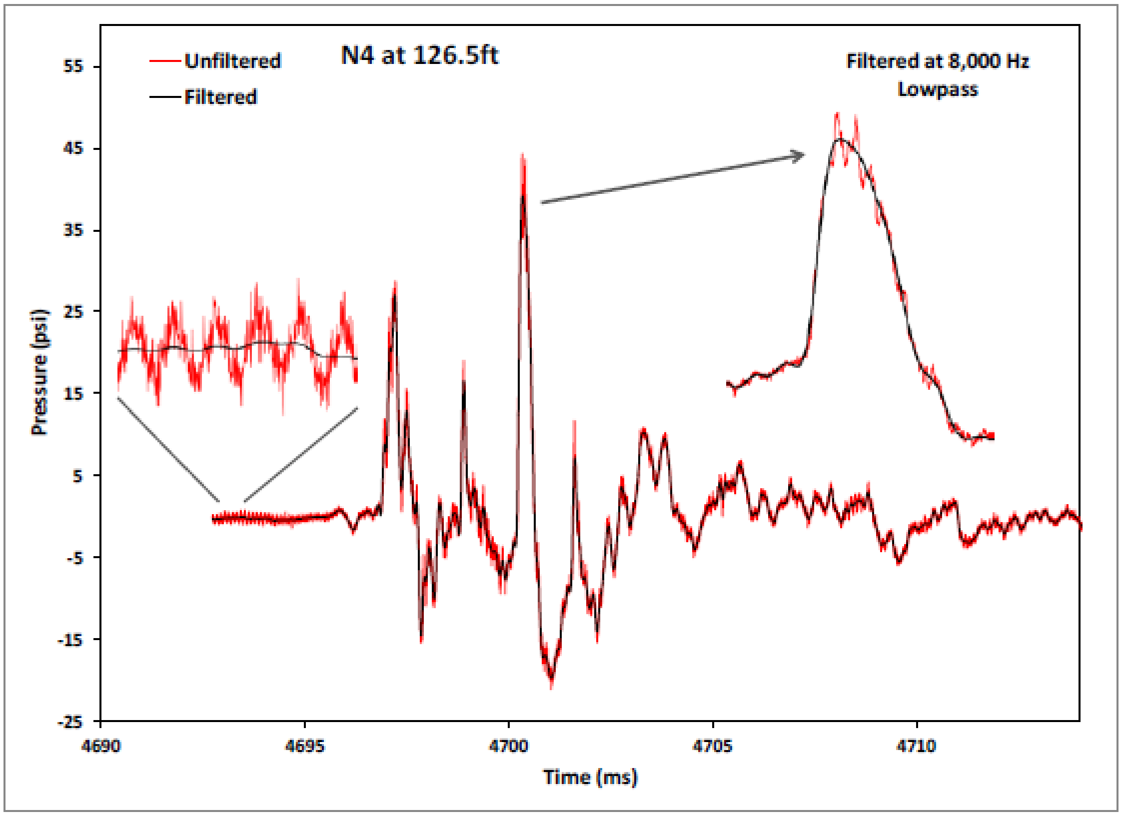
Figure 45. Near Field Pressure Sensor Deployment Locations



Note:
Example of filtering near to the pier where a higher filter was selected; noise is enlarged on the left and the peak is enlarged on the right.

Figure 46. Example of Filtering near the Pier

At distances just beyond the BAS, the peak pressure did not rise as quickly and exhibited lower frequency content. Therefore, a lower frequency filter was used to remove noise without degrading the actual peak pressure. This is shown in Figure 47 for location N4 where an 8,000 Hz low-pass filter was used. The noise is shown on the left and is mostly removed by this filter choice. The peak is enlarged on the right showing that the pressure rise is matched in the filtered waveform and the peak amplitude is not degraded.



Note:
Example of filtering farther from the pier, where lower filter is chosen; noise is enlarged on the left and the peak is enlarged on the right.

Figure 47. Example of Filtering farther from the Pier

6.2.2.2. North Line Measurements Outside the BAS

Pressures for near field sensors along the north line were reviewed to determine the peak values and the times at which the peaks occurred. It was determined that peaks occurred at each sensor location over a range of arrival times that could be correlated with detonation times of charges located close to the array (e.g., at the north end of the pier in the direction of detonation).

Figures 47, 49 and 50 show the whole waveform records at locations N1 (inside the BAS), N3, and N5, respectively. In each figure, specific peaks of interest are identified as Peak 1 and Peak 2. When tracking Peak 1 as a function of distance at sensor locations, the amplitude attenuated as expected. However, Peak 2 increased in amplitude with distance beyond the BAS. Subsequently, the maximum pressure at N1 occurred in Peak 1, while Peak 2 provided the highest pressure at the farther locations. Figures 51 and 52 show time histories for Peaks 1 and 2 at increasing distances from the Pier to illustrate this effect.

While the amplitude behavior of Peak 2 was not expected, it can be explained based on the wave propagation complexities arising from the nature of the Pier structure and interactions of a large number of small detonating charges. In essence, the void spaces within the concrete Pier created complex wave travel paths and interactions, resulting in constructive as well as destructive interference of peaks. The additive effect of Peak 2 with distance was enhanced as the sequence of shot moved to the north. In addition, the BAS disrupted the shock front and created pressure time histories with later arriving peaks that increased with distance rather than decreased with distance outside the bubble curtain. Although the effectiveness of the bubble curtain can be evaluated, the passage of the first shock front most likely disturbed the bubbles to allow a certain amount of blast energy to pass and created an additive effect at later arriving peaks. Such an effect can help explain data scatter in the attenuation model.

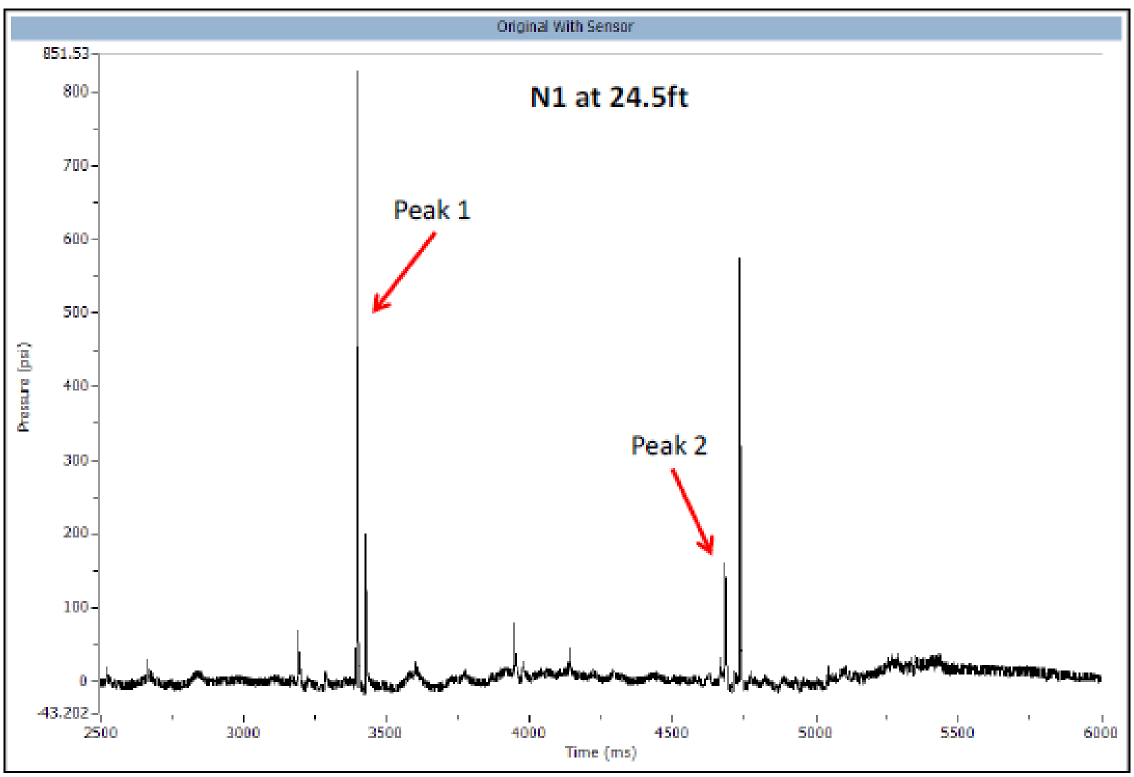


Figure 48. Pressure Time History of the Entire Blast at Location N1 inside the BAS, with Peaks 1 and 2 Highlighted

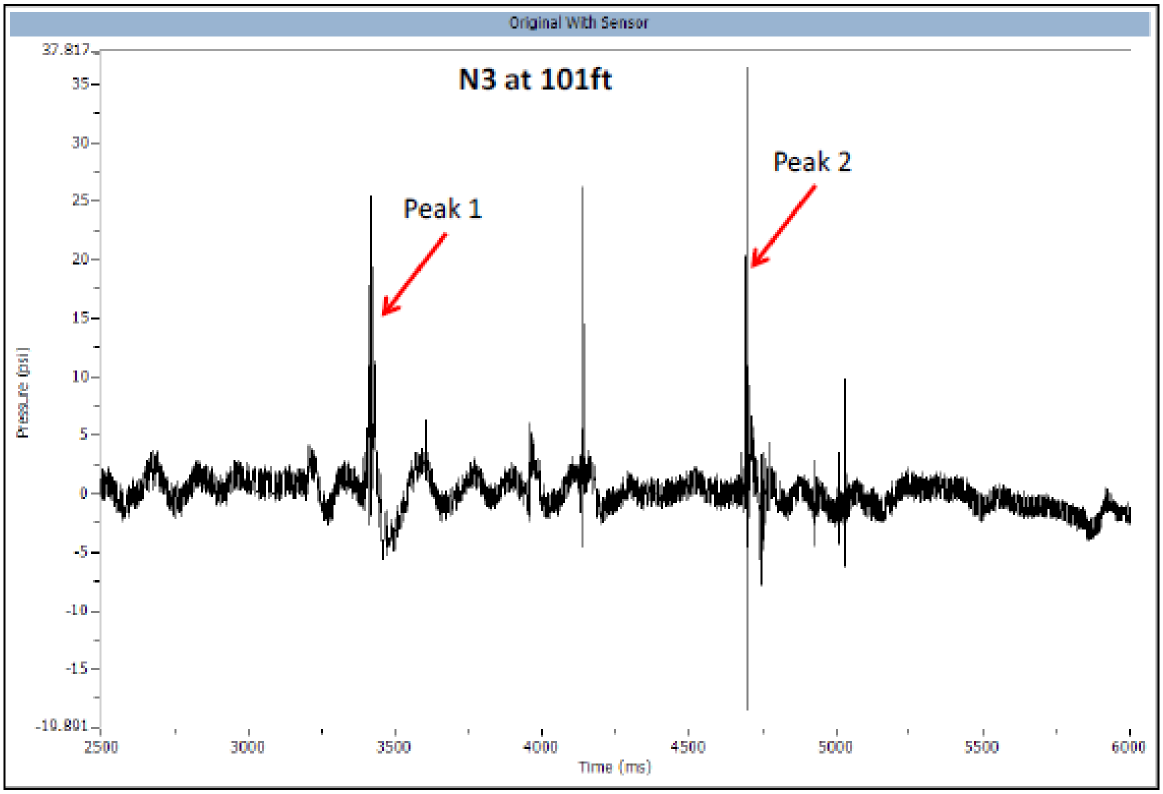


Figure 49. Pressure Time History of Peaks 1 and 2 at Location N3, outside the BAS

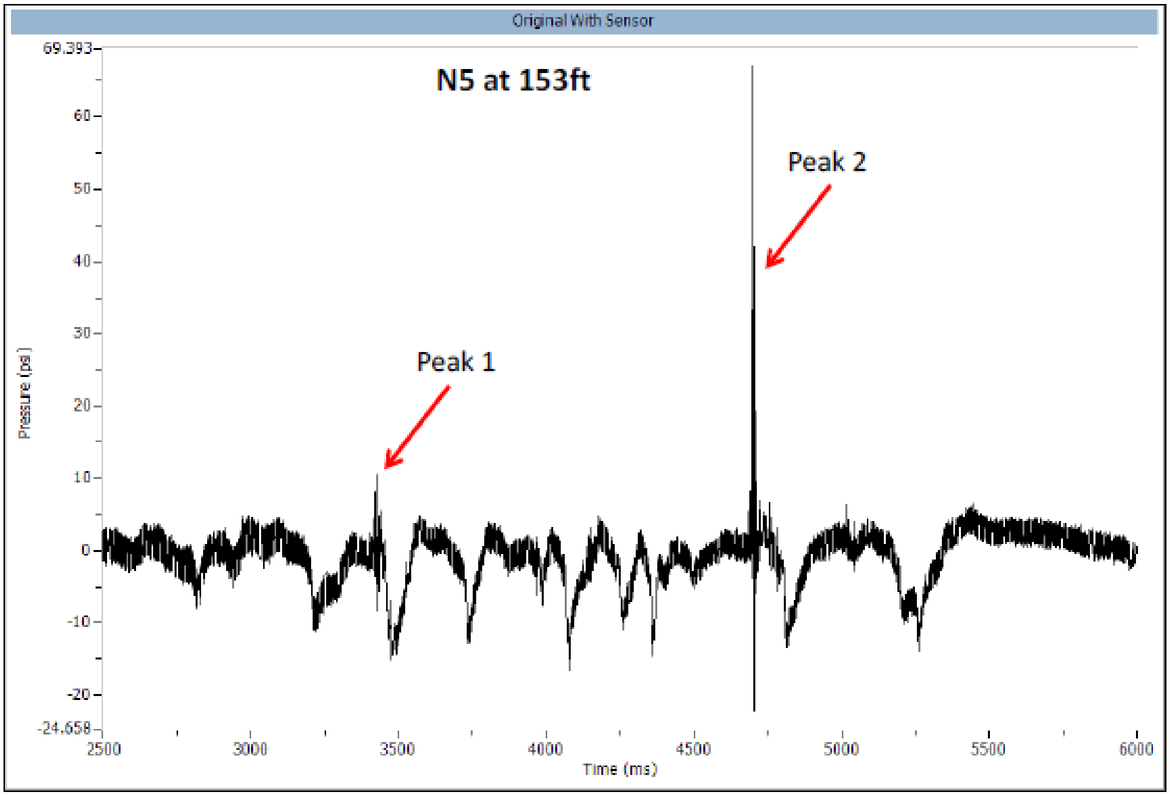


Figure 50. Pressure Time History of Peaks 1 and 2 at Location N5

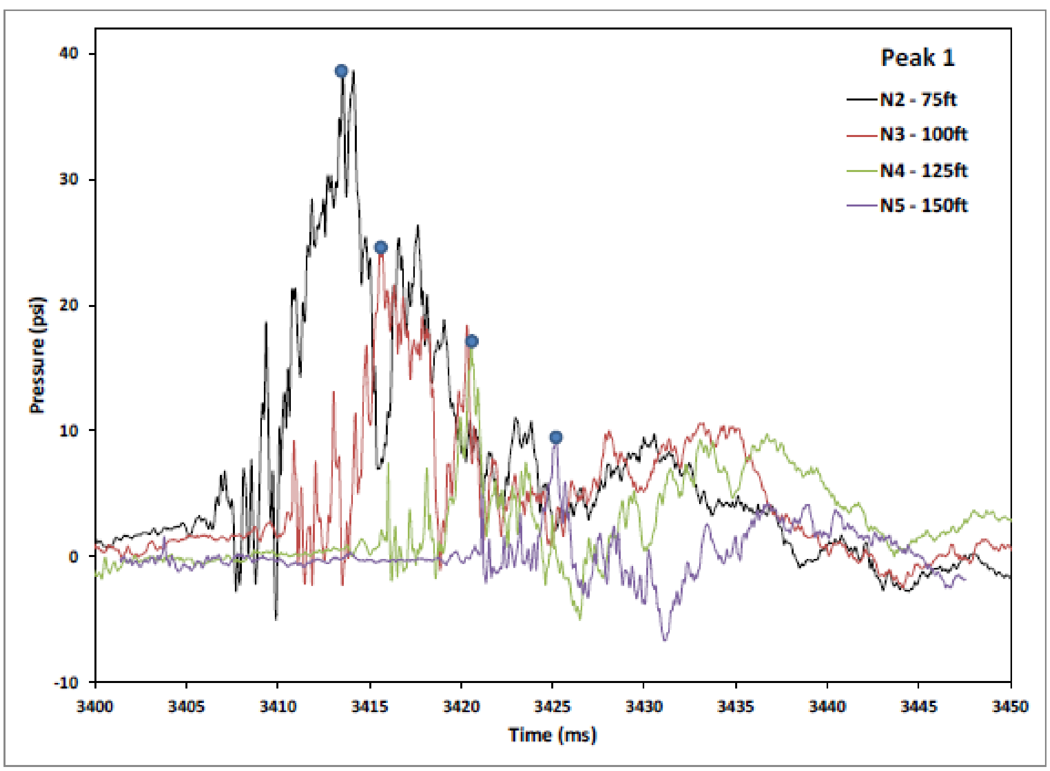


Figure 51. Attenuation of Peak 1 Pressure with Distance outside the BAS

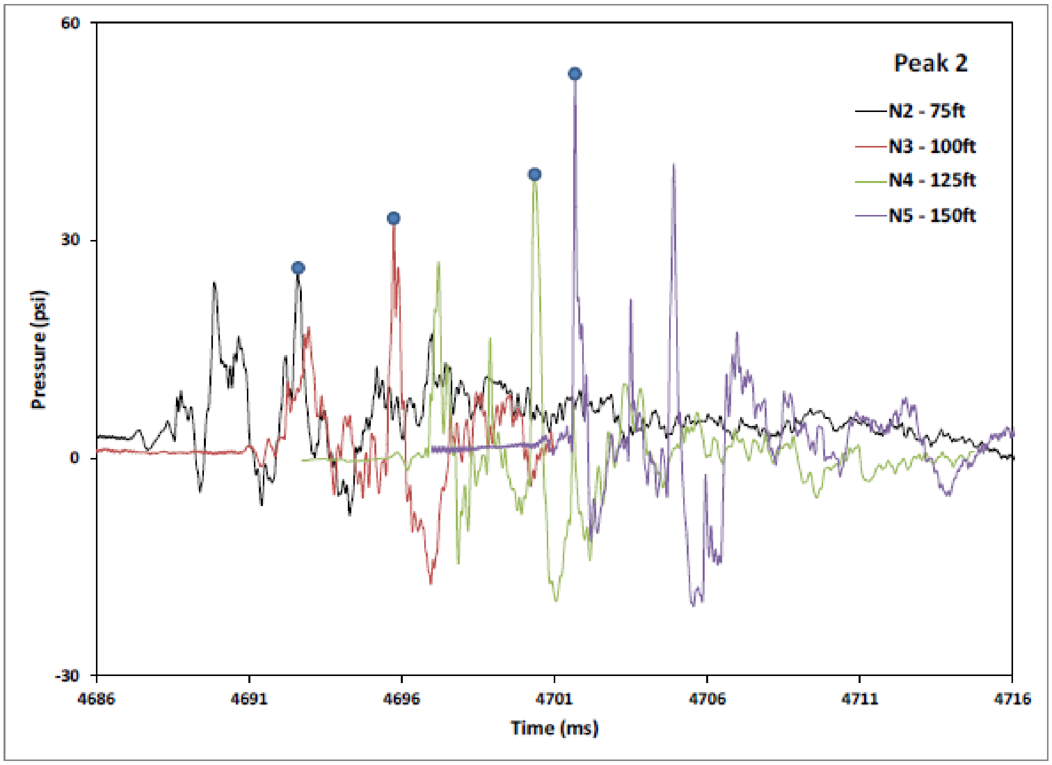


Figure 52. Increase of Peak 2 Pressure with Distance outside the BAS

6.2.2.3. BAS EFFECTIVENESS: COMPUTING THE REDUCTION IN PRESSURE FROM THE BAS

The efficiency of the BAS in terms of percent reduction of the blast pressure from inside the bubble curtain to outside was performed. Calculations of this reduction were performed for a number of scenarios based on the cross-section geometry of the bubble curtain shown in Figure 53. The BAS centerline (CL) distance from the Pier and width of bubbles at the surface, d, were the two key parameters. From these two parameters, the locations of the inside pressure, P1, and exiting pressure, P2, at the sensor depth of 20 ft could be determined. Because the BAS is a dynamic phenomenon whose bubble strength varies in time and location around the Pier, a range of possible distances between the Pier and BAS centerline (D_{cl}) and bubble curtain widths (d) were considered. Careful review of Demonstration Project as-built plans, and photographs and videos of the operating BAS from multiple angles resulted in eight total scenarios with specific centerline distances and widths given in Table 13 used to calculate the BAS efficiency.

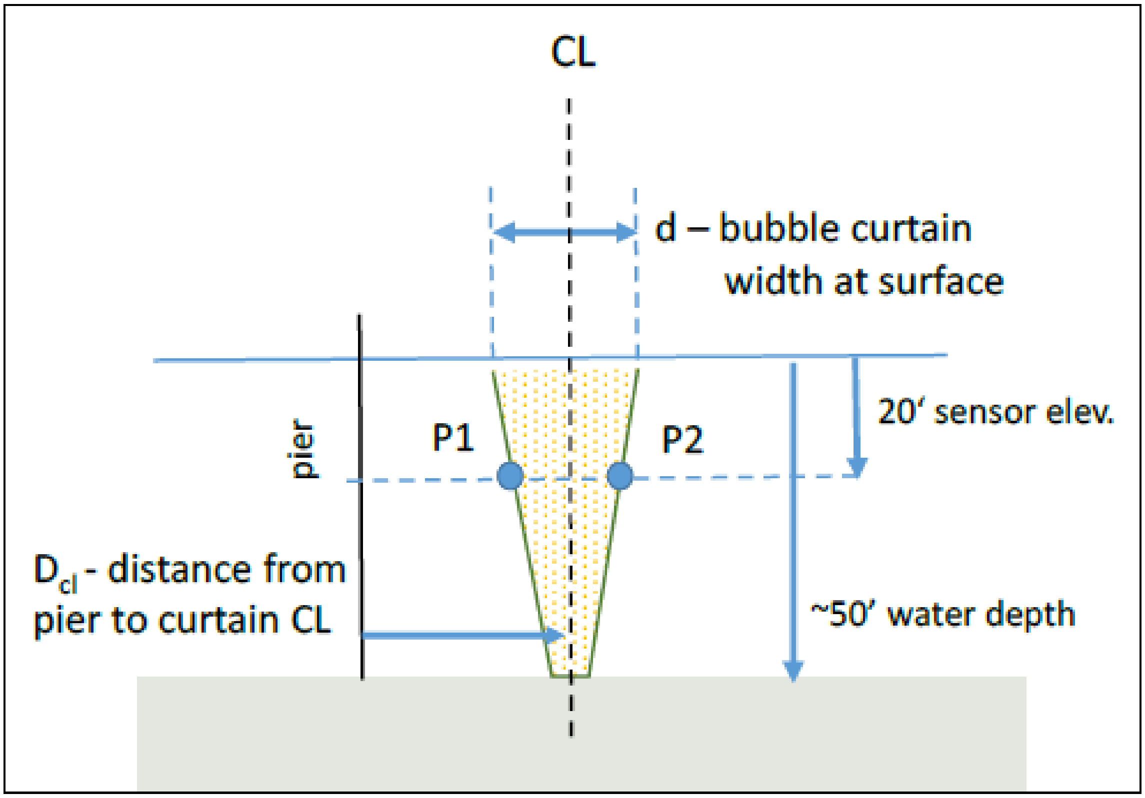
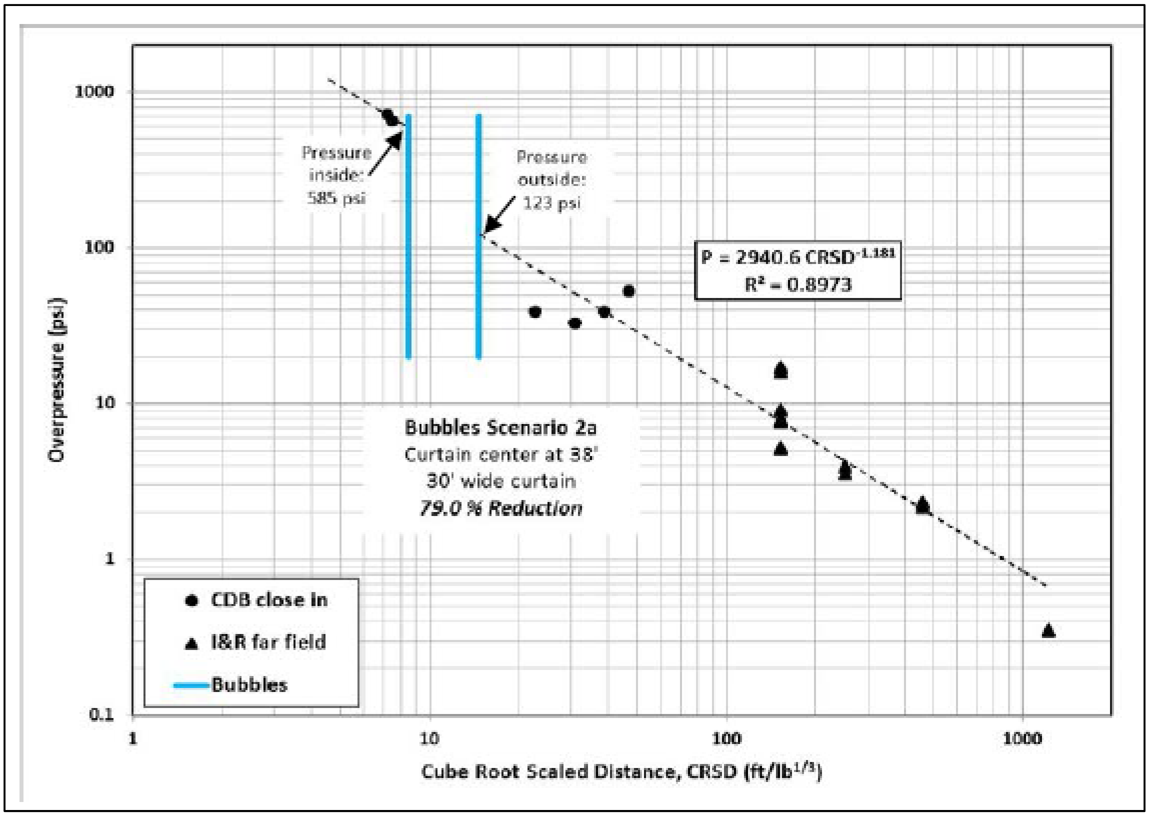


Figure 53. Cross-Section of BAS Bubble Curtain with Relevant Geometric Relations

Table 13. BAS geometry scenarios used for efficiency calculations

Scenario	Distance from Pier to bubble curtain center	Bubble curtain width at surface
	(feet)	(feet)
1a	38	25
1b	40	25
1c	42	25
1d	44	25
2a	38	30
2b	40	30
2c	42	30
2d	44	30

The attenuation relationship established for the Pier was used to calculate pressures P1 and P2 at their respective scaled distances. The attenuation was assumed to have the same slope inside the BAS passing through the pressure measurement data points at E1 (713.5 psi) and N1 (653.3 psi). Figures 54 and 55 visually show this for two possible scenarios along with the calculated pressures at P1 and P2 and the resulting efficiency computed as percent reduction in pressure from P1. Scenario 2a, shown in Figure 53, resulted in the highest calculated pressure reduction of 79 percent, while scenario 1d, shown in Figure 54, gave the lowest reduction at 75 percent. Table 14 summarizes the calculated efficiency for all eight scenarios. The overall average pressure reduction across the BAS was computed as 77 percent using all likely bubble curtain geometries and positions.



Note:
Reduction of blast water pressure by BAS bubble curtain with geometry scenario 2a; calculated pressures are shown at locations P1 and P2, along with calculated percent reduction in pressure across the BAS.

Figure 54. Reduction of Blast Water Pressure by BAS Bubble Curtain with Geometry Scenario 2a

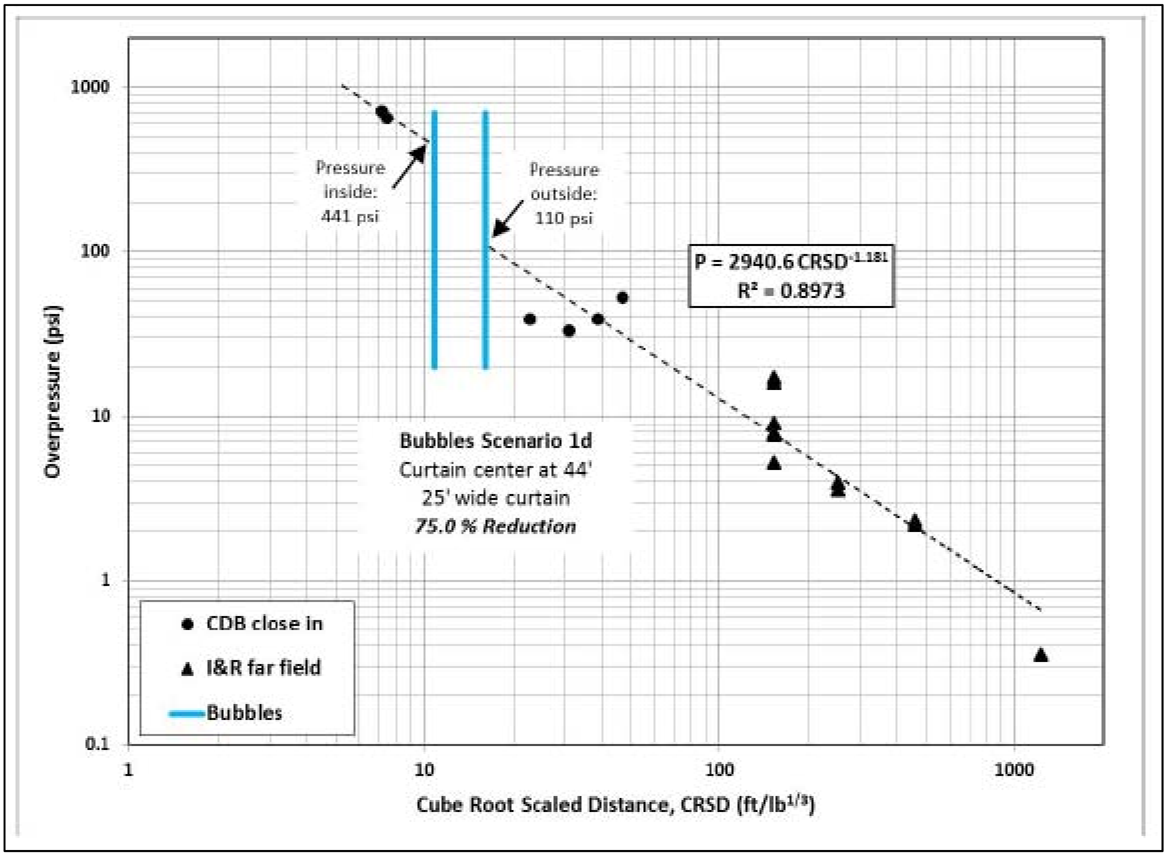


Figure 55. Reduction of Blast Water Pressure across the BAS Bubble Curtain for Geometry Scenario 1d

Table 14. Summary of calculated BAS efficiencies for all geometry scenarios; overall average efficiency

Scenario	Distance from pier to bubble curtain center	Bubble curtain width at surface	Estimated bubble curtain width at 20ft depth of	Overpressure at edges of bubble		Calculated BAS efficiency (P1-P2)/P1*100%	Overall average BAS efficiency for all scenarios
	(ft)	(ft)	(ft)	Inside (P1) (psi)	Outside (P2) (psi)		
1a	38	25	17.4	550	127	76.9%	77.0%
1b	40	25	17.4	509	121	76.2%	
1c	42	25	17.4	473	116	75.6%	
1d	44	25	17.4	441	110	75.0%	
2a	38	30	20.4	585	123	79.0%	
2b	40	30	20.4	539	117	78.3%	
2c	42	30	20.4	499	112	77.6%	
2d	44	30	20.4	465	107	77.0%	

6.2.3. Results Related to Fish Criteria

The peak pressure levels and cSEL values for all of the monitoring locations are shown in Figure 56 along with the corresponding fish criteria. As discussed in Section 5.2, the measured peak pressure levels fall on or above the calculated curve. For cSEL, the measured levels fall on or below the calculated curve except at one near field measurement location.

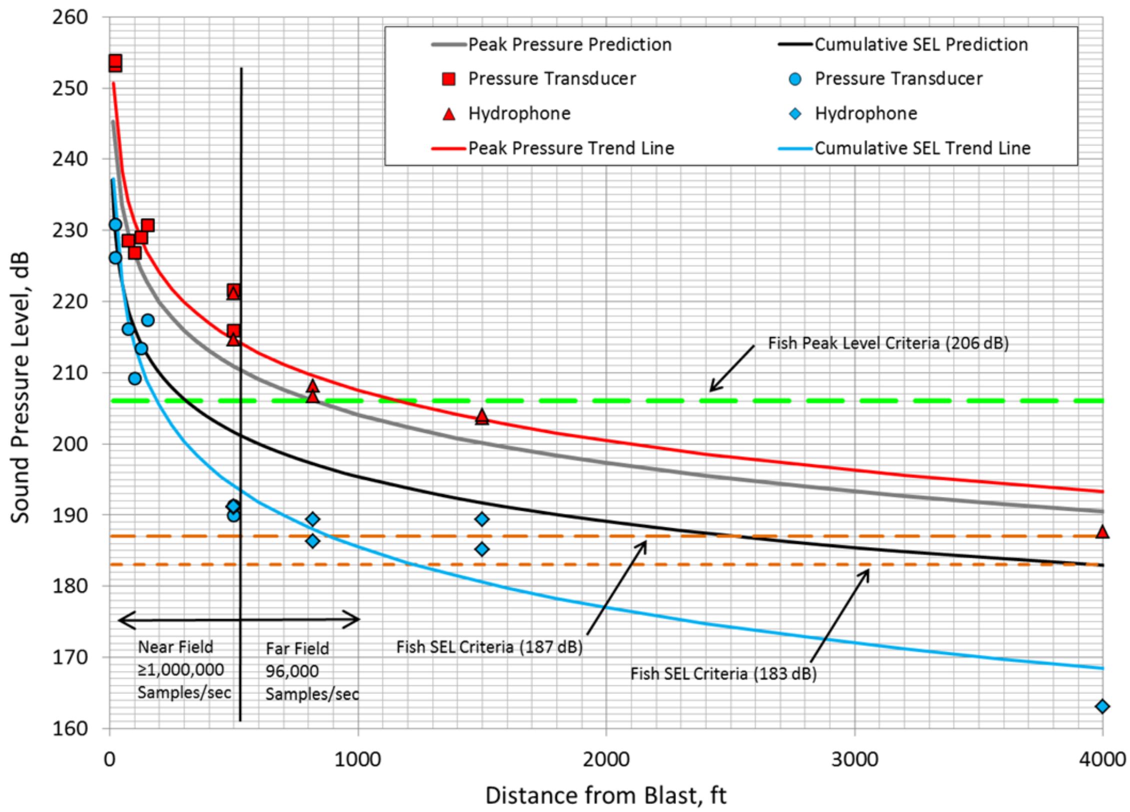


Figure 56. Measured and Calculated Peak Pressure Level and Cumulative Sound Exposure Level Results with Indicated Fall-Off Rates

Also, Figure 56 shows the fall-off rates for the measurement trend lines and calculated curves. These are in the form of yy Log (x) where x is the distance to the receiver location and yy is rate at which the level decreases with the logarithm of distance; the higher the yy values, the faster the levels decrease with distance. The fall-off rate for the measured L_{pk} was approximately 23.9 times the logarithm of distance while the calculated rate was 22.6. As a result, even though measured peak is higher than the calculated out to 4,000 feet, at further distances, the measured values would be less than the calculated. For cSEL, fall-off rate for the measurements was approximately 28.4 compared to 20.9 for the calculated. As a result, even though the measured and calculated levels were close in level out to about 200 feet, at farther distances they separate because of the greater fall-off rate of the measure values. At 500 feet the measured cSEL was about 5 dB below the calculated and at 4,000 feet this difference dropped to about 15 dB.

The RMS sound pressure level results are shown in Figure 57 along with the calculated level, RMS criterion, and trend line of the measured data. Similar to the cSEL results, the fall-off rate of the measured RMS levels is greater than the calculated rate, and the measured levels are below the calculated for 500 feet and beyond. The calculated and measured fall-off rate is the same as the corresponding rate of the cSEL (see Figure 55). The calculated and measured distances to the peak, cSEL, and RMS levels are shown in the Table 15.

Table 15. Summary of the calculated distances to the fish criteria

Criteria	Threshold	Calculated Distance	Measured Distance
Peak Pressure	206 dB	820 feet	1,165 feet
Cumulative SEL, ≥ 2 grams	187 dB	2,550 feet	889 feet
Cumulative SEL, < 2 grams	183 dB	4,000 feet	1,230 feet
RMS Sound Pressure Level	150 dB	68,000 feet	4,752 feet

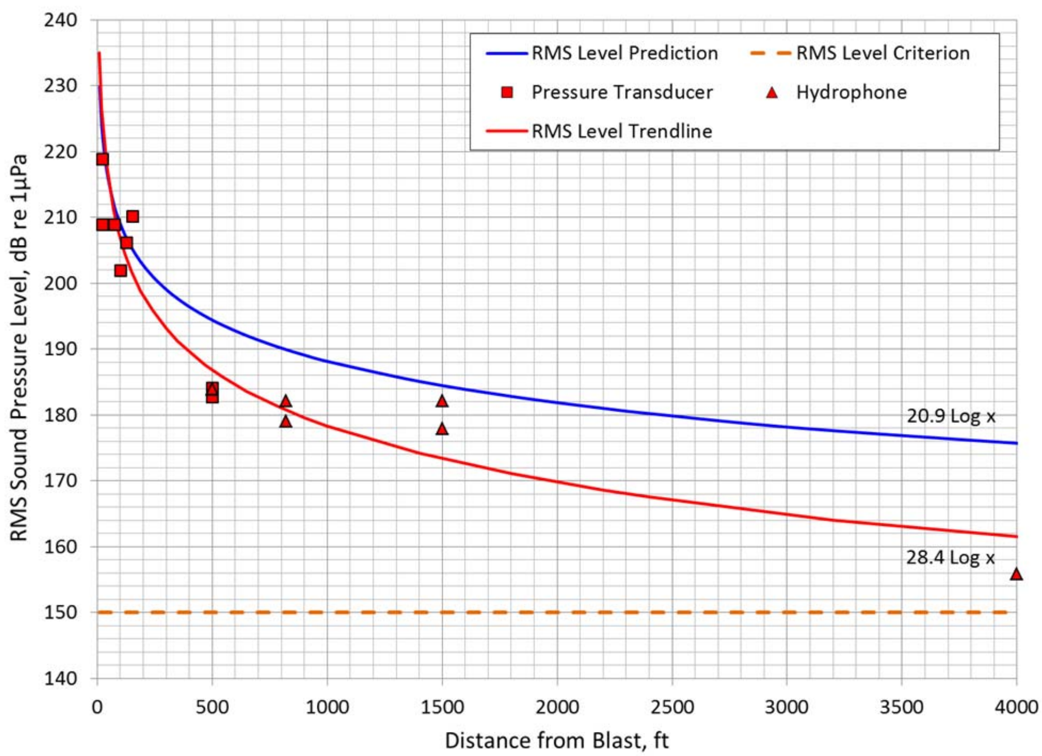


Figure 57. Comparison of Measured RMS Levels to Calculated and Data Trend Line

6.2.4. Results Related to Marine Mammals

To compare the measured cSEL values to the marine mammal criteria for seals, sea lions, and porpoises, the weighting was first applied to the measured results. The same weighting factors used to produce the calculated levels shown in Figures 24, 25 and 26 were subtracted from the measured cSEL for each of the three species. These results are shown in Figure 58 along with the calculated levels, which have fall-off rates ranging between 21.6 and 22.7 Log distance. Similar to the cSEL results in Figure 56, the weighted values fall on or below the calculated levels, except at the 153-foot location north of Pier E3. The measurements were also used to establish logarithmic trend lines through the data points, as shown in Figure 59. As in the case of the unweighted cSEL trend lines considered for fish, those for marine mammals display also fall-off rates higher than the calculated fall-off rates. With the added effect of the species weightings, the marine mammal fall-off rates are actually slightly greater than the unweighted cSEL fall-off rates.

For all species of marine mammal, the same criterion level for GI tract, lung injury and mortality damage applies. As a conservative measure, the criteria for a harbor seal pup was used for all marine mammals as these are the most abundant and smallest marine mammal species in the project area. In Figure 60, the peak pressure levels measured during the implosion are compared to the GI criterion and the calculated levels. For all locations outside the BAS, the measured peaks were below the criteria. The measured values display the same relation to the calculated values as discussed in regard to fish peak criteria (see Figure 56).

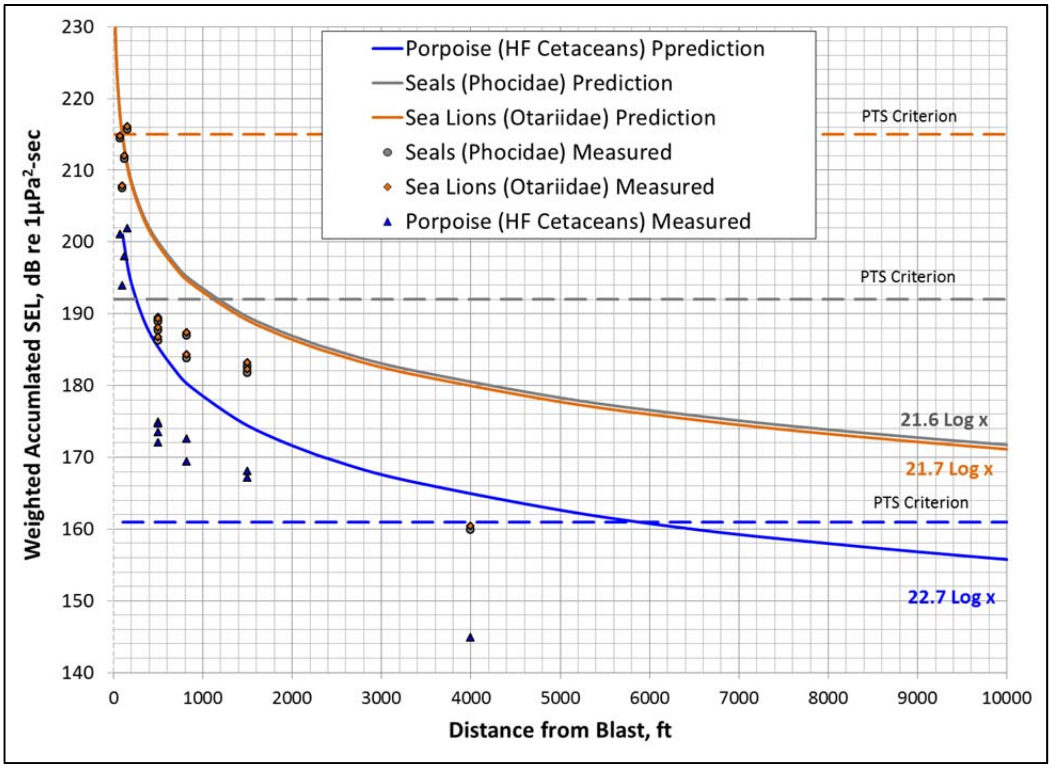


Figure 58. Marine Mammal Weighted Measured Levels Compared to Calculated Values and Criteria

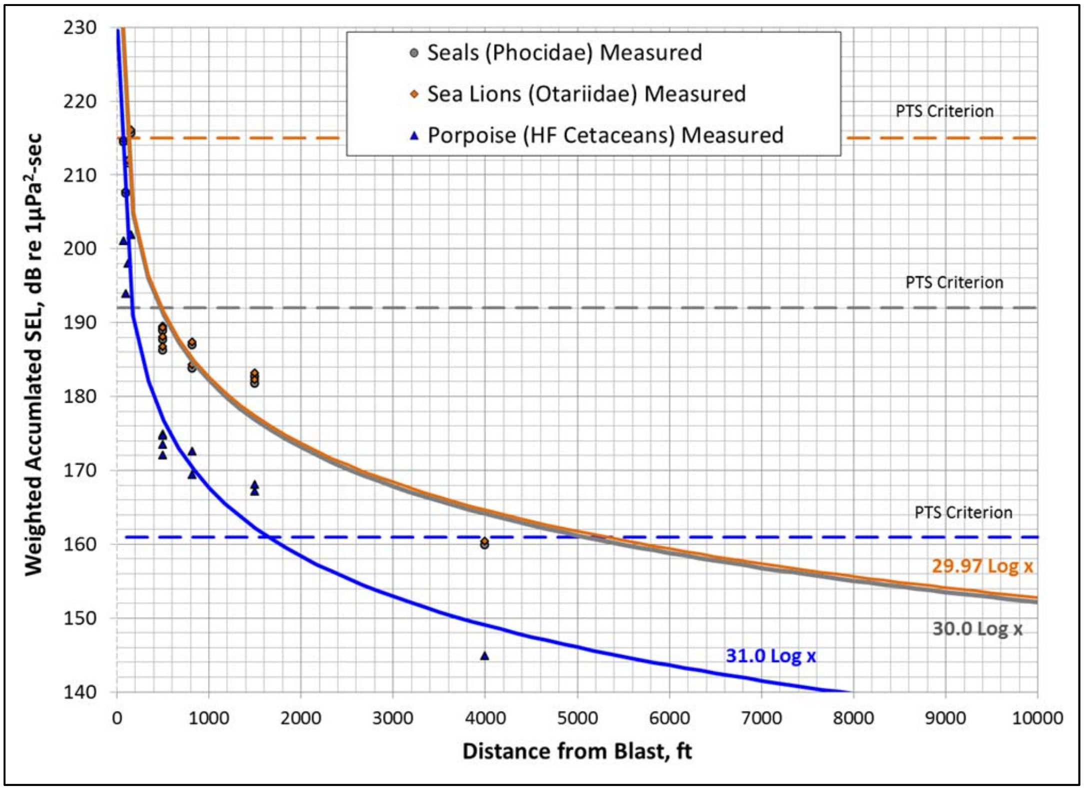


Figure 59. Marine Mammal Weighted Measured Levels and Trend Lines Compared to Criteria

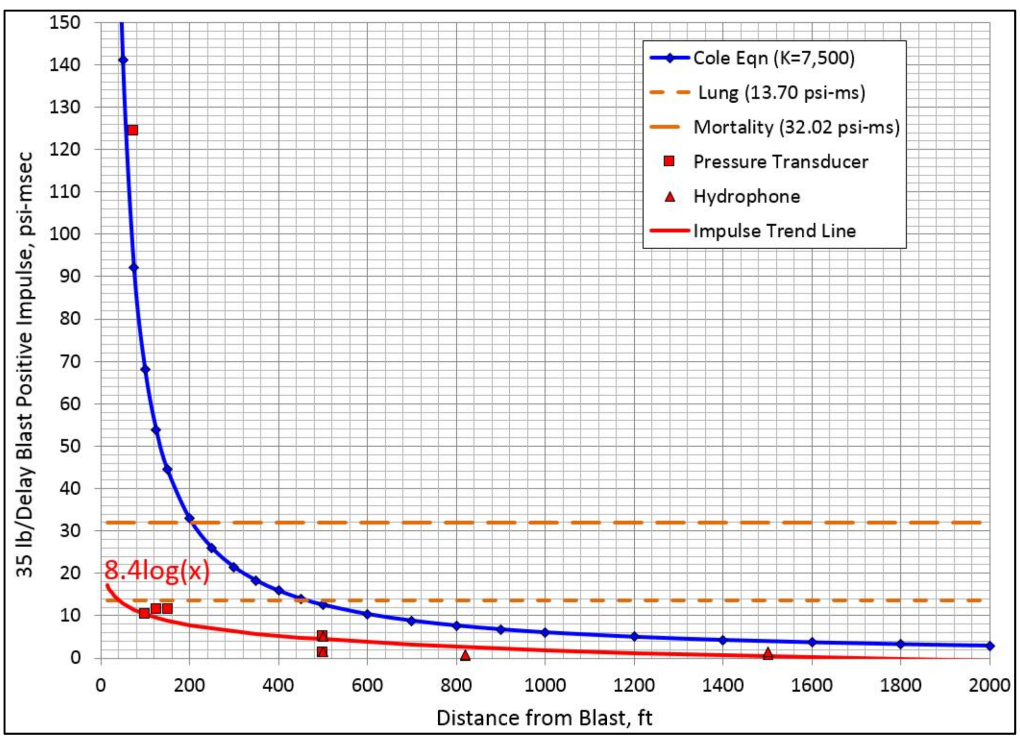


Figure 60. Summary of Impulse Results Compared to the Calculated and the Marine Mammal Criteria

Table 16 summarizes the distances to all marine mammal thresholds from Pier E3 based on the measurements for the implosion event. Because the distance to the cSEL threshold was always greater than to the Lpk threshold for behavior, TTS and PTS, all values shown in Table 16 are cSEL levels.

Table 16. Summary of the calculated distances to the marine mammal criteria

Criteria	Pacific Harbor & Northern Elephant Seal (Phocidae)			Sea Lions (Otariidae)			Porpoises (High Frequency Cetaceans)		
	Threshold	Calculated Distance	Measured Distance	Threshold	Calculated Distance	Measured Distance	Threshold	Calculated Distance	Measured Distance
Behavior	172 dB	9,700 feet	2,460 feet	195 dB	800 feet	387 feet	141 dB	44,500 feet	8,171 feet
TTS	177 dB	5,700 feet	1,658 feet	200 dB	470 feet	261 feet	146 dB	26,500 feet	5,580 feet
PTS	192 dB	1,160 feet	507 feet	215 dB	97 feet	80 feet	161 dB	5,800 feet	1,777 feet
GI Tract	237 dB	35 feet	14.5 feet	237 dB	35 feet	14.5 feet	237 dB	35 feet	14.5 feet
Lung Injury	13.7 psi-ms	450 feet	<100 feet	13.7 psi-ms	450 feet	<100 feet	13.7 psi-ms	450 feet	<100 feet
Mortality	32.02 psi-ms	205 feet	<100 feet	32.02 psi-ms	205 feet	<100 feet	32.02 psi-ms	205 feet	<100 feet

6.2.5. Tables of Measured Levels

All near and far field peak pressures are summarized in Table 17. These are the same values that were used to plot Figure 55. Within the BAS, the peak levels ranged from 253.1 to 253.8 dB. The peak pressure levels outside the BAS were 228.5 dB at 74.5 feet to 231.2 dB at 153 feet. While the peak levels increased slightly with distance between 74.5 and 153 feet, note the close proximity of each of these measurements. The PCB and hydrophone transducers at 500 feet were within 0.5 to 1.2 dB of each other, with the measurements in the east direction being higher than the south by approximately 6 dB because of some directionality in the implosion. At 1,500 feet from Pier E3, the measurements in both directions were approximately 204 dB, which was below the 206 dB peak threshold.

Table 17. Summary of peak pressure levels measured at each near and far field location

Direction	Distance	Measurement Transducer	Peak Pressure, L_{pk}
North	24.5 feet	PCB	253.1 dB*
	74.5 feet	PCB	228.5 dB*
	101 feet	PCB	227.2 dB*
	126.5 feet	PCB	229.0 dB*
	153 feet	PCB	231.2 dB*
East	23.5 feet	PCB	253.8 dB*
	500 feet	PCB	221.6 dB*
		Hydrophone	221.1 dB

Table 17. Summary of peak pressure levels measured at each near and far field location			
Direction	Distance	Measurement Transducer	Peak Pressure, L_{pk}
	820 feet	Hydrophone	208.2 dB
	1,500 feet	Hydrophone	203.6 dB
South	500 feet	PCB	215.9 dB*
		Hydrophone	214.7 dB
	820 feet	Hydrophone	206.7 dB
	1,500 feet	Hydrophone	204.1 dB
	4,000 feet	Hydrophone	187.7 dB
*The low pass filter used on the PCB data reduced peak pressures by 0.4 to 2.6 dB from the raw signals.			

The cSEL levels for all of the measurement locations are shown in Table 18. These range from 230.8 dB inside the BAS to 162.9 dB 4,000 feet to the south of the former Pier E3. The L_{RMS} was calculated by dividing the total duration of the blasting event, which was 5.283 seconds, by total energy accumulated during the event.

Table 18. Summary of SEL levels measured at each near and far field location			
Direction	**Distance**	**Measurement Transducer**	**Cumulative SEL, cSEL**
North	24.5 feet	PCB	226.1 dB*
	74.5 feet	PCB	216.1 dB*
	101 feet	PCB	209.2 dB*
	126.5 feet	PCB	213.4 dB*
	153 feet	PCB	217.5 dB*
East	23.5 feet	PCB	230.8 dB*
	500 feet	PCB	189.9 dB*
		Hydrophone	188.5 dB
	820 feet	Hydrophone	189.3 dB
	1,500 feet	Hydrophone	185.3 dB
South	500 feet	PCB	191.3 dB*
		Hydrophone	191.1 dB
	820 feet	Hydrophone	186.2 dB
	1,500 feet	Hydrophone	184.4 dB
	4,000 feet	Hydrophone	162.9 dB
*Unfiltered signals contained too much high frequency noise to calculate cSEL so all calculations were conducted with filter signals.			

The values for each near and far field location are summarized in Table 19. Similar to the peak and cSEL levels, the near field L_{RMS} get higher with distance. The RMS pressure levels were below the 150 dB L_{RMS} criteria for behavioral response to fish at 4,000 feet.

Table 19. Summary of L_{RMS} levels measured at each near and far field location

Direction	Distance	Measurement Transducer	RMS Level, L_{RMS}
North	24.5 feet	PCB	211.6 dB*
	74.5 feet	PCB	201.6 dB*
	101 feet	PCB	194.7 dB*
	126.5 feet	PCB	199.0 dB*
	153 feet	PCB	203.0 dB*
East	23.5 feet	PCB	216.4 dB*
	500 feet	PCB	175.4 dB*
		Hydrophone	174.0 dB
	820 feet	Hydrophone	174.8 dB
	1,500 feet	Hydrophone	171.3 dB
South	500 feet	PCB	176.3 dB*
		Hydrophone	176.1 dB
	820 feet	Hydrophone	171.2 dB
	1,500 feet	Hydrophone	169.4 dB
	4,000 feet	Hydrophone	147.9 dB

*Unfiltered signals contained too much high frequency noise to calculate L_{RMS} so all calculations were conducted with filter signals.

The final metric calculated for the blasting event was impulse. Impulse is considered the summation of the positive energy in the greatest pressure pulse during a blast. However, because this Demonstration Project included 588 individual blasts, the greatest absolute peak pressure did not necessarily occur in the positive energy direction at the far field locations. Therefore, the energy summed for the impulse metric at each position may not have coincided with the L_{pk} discussed previously. At 500 feet in the south direction, for instance, the peak pressure level in Table 17 occurred in a negative direction, and the highest positive pressure pulse used to determine the impulse value occurred at a slightly later time in the blasting event.

Table 20 summarizes the impulse pressures measured at each location in the near field and far field. At the two near field measurement locations inside the BAS, the impulse values ranged from 244.1 to 283.0 psi-ms, which reduced to 10.4 psi-ms at 101 feet. At 500 feet, direction of the measurement affected the impulse. In the east direction, the L_{pk} was in the positive direction and had a fast rise time, as discussed above, which translates to little energy in the impulse summation of that peak. In the south line, however, the L_{pk} was in the negative direction, which means the positive energy pulse used to calculate the impulse had a slower rise time and included more energy for the summation of the impulse metric. By 1,500 feet, the impulse measured at around 1 psi-ms and was less than

0.1 psi-ms at 4,000 feet. At all locations outside the BAS, the measured impulse values were below the lung injury and mortality thresholds.

Table 20. Summary of impulse values measured at each near and far field location

Direction	Distance	Measurement Transducer	Impulse Value
North	24.5 feet	PCB	283.0 psi-ms*
	74.5 feet	PCB	128.4 psi-ms*
	101 feet	PCB	10.4 psi-ms*
	126.5 feet	PCB	11.4 psi-ms*
	153 feet	PCB	11.5 psi-ms*
East	23.5 feet	PCB	244.1 psi-ms*
	500 feet	PCB	1.2 psi-ms*
		Hydrophone	1.5 psi-ms
	820 feet	Hydrophone	0.5 psi-ms
	1,500 feet	Hydrophone	0.7 psi-ms
South	500 feet	PCB	5.1 psi-ms*
		Hydrophone	5.0 psi-ms
	820 feet	Hydrophone	0.7 psi-ms
	1,500 feet	Hydrophone	1.4 psi-ms
	4,000 feet	Hydrophone	0.01 psi-ms

*Filtered signals were used to calculate the impulse metric.

6.2.5.1. DISCUSSION

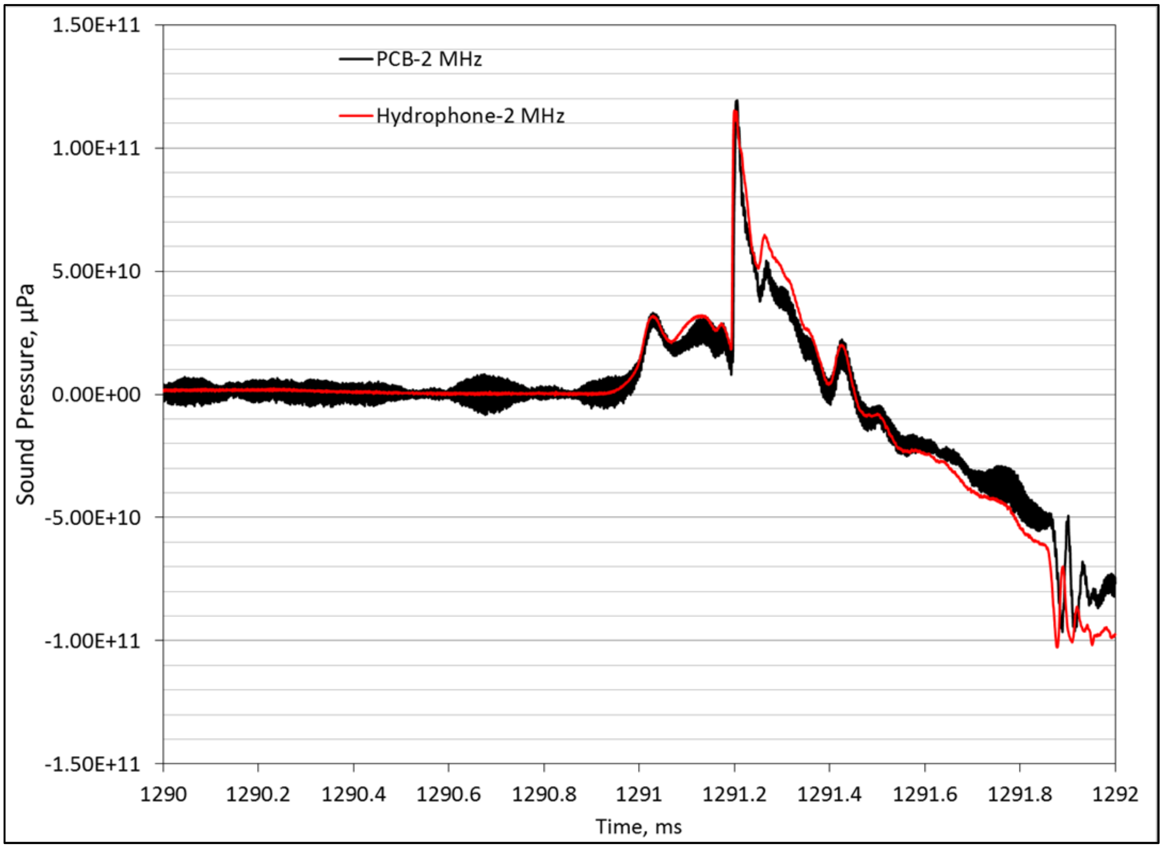
As shown in Figure 56, and based on the assumptions used to calculate noise levels, in general terms, these estimations appear to represent actual measured levels well. For peak pressure level, it was generally found that the measured levels were only slightly greater than the estimated (by about 2 to 3 dB). The decrease in measured peak pressure level with distance was remarkably similar to that estimated using conventional blast pressure calculation techniques, which are described in the Calculated Levels section of this report.

As noted in regard to Figure 39 for the east monitoring line, the peak level was determined by just a few high level peaks out of the 588 individual blasts. To the east face of Pier E3, the distance to the blasts measured virtually the same as the implosion progressed from south to north. The expected pressures produced by individual charges were quite uniform even for the range of 21 to 35 lbs/delay (see Table 9), and the reason for elevated levels for two out of the 588 blasts is unclear. Potential causes for these higher levels could be reduced confinement of these individual charges, inconsistency in the BAS along the path taken by these particular charges, and/or constructive interference of individual charges. In future calculations, it may be appropriate to consider the estimated peak pressures statistically; that is, comprised of an expected average peak level based on calculations similar to those described and an additional factor or offset to account for the probability of a few peaks of greater than calculated amplitude. Based on the results shown in Figure 56, the calculated fall-off rate applies, regardless of the possible occurrence of random, higher level blasts.

For the cSEL calculations, the trend through the measurements falls off at a more rapid rate than calculated. This higher fall-off may be expected from the discussion regarding the cSEL calculation and influence of the surface relief wave at farther distances from the source. At the farther distances, the path length difference between the direct and reflected pulses becomes smaller and smaller, improving the chance for interference between the two waveforms. As noted, this will only tend to decrease the cSEL from that expected for the direct waveform only. This effect would become even greater at larger distances from the pier. Given the rather extreme distances calculated for some of the criteria (e.g. the fish RMS criterion and porpoise cSEL criteria), it may be appropriate to use the fall-off determined experimentally rather than the calculated rates. There is also some indication based on the 4,000 feet data that even the experimental fall-off rate would be conservative at the farther distances.

6.2.5.2. HYDROACOUSTIC/ UNDERWATER PRESSURE MONITORING

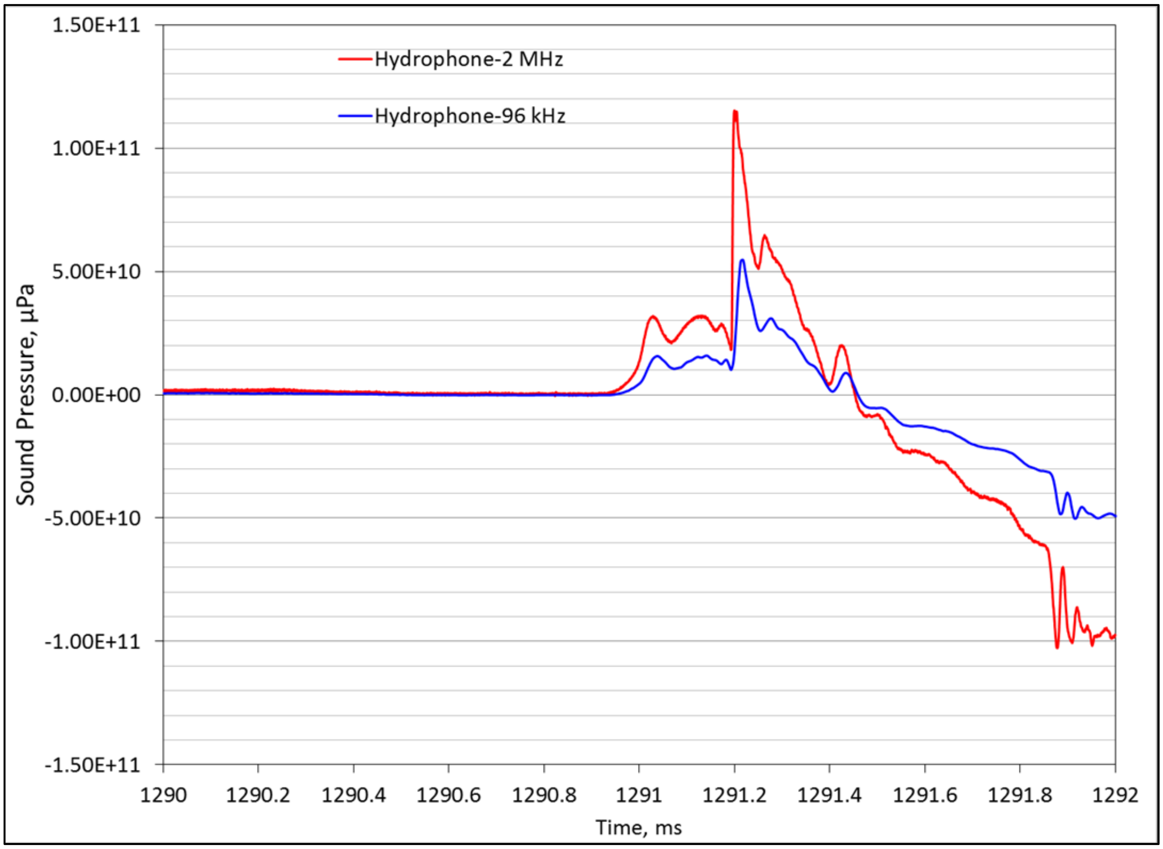
Comparative data collection between pressure transducers and hydrophones at 500 and 820 feet were originally included in the far field hydroacoustic monitoring plan. Unfortunately, the pressure transducer acquisition at 820 feet failed, leaving only the 500 feet distance for comparison. However, results from three different acquisition system configurations were produced at both 500 feet distances. These included a pressure transducer with an upper acoustic frequency response range of about 1,000,000 Hz, sampled at 2,000,000 S/s, a hydrophone with an upper range of 170,000 Hz, sampled also at 2,000,000 S/s, and a hydrophone sampled at 96,000 S/s. The waveforms produced by the pressure transducer and the hydrophone are compared in Figure 61, as sampled at 2,000,000 S/s. Both devices track the peak pressure quite well and are virtually identical. For the pressure transducer, when the amplitude is less than about 5×10^{10} μPa, the signal contains electronic noise seen as the fluctuation around zero and mean level above zero. The hydrophone is inherently less noisy and has a higher sensitivity than the pressure transducer. As a result, the hydrophone is preferred over the pressure transducer for use as close as possible to the implosion location. However, its upper range is limited, compared to the pressure transducer, and it could overload if used too close to the blast detonations.



Note:
Pressure waveform at 500 feet from the east for a pressure transducer and hydrophone, both sampled at 2,000,000 samples/second.

Figure 61. Pressure Waveform at 500 feet from the East (1)

Figure 62 compares the same waveform, as measured by the hydrophone, but sampled at two different rates: 2,000,000 S/s and 96,000 S/s. The lower sampling rate does not capture the waveform to the same fidelity as the higher rate and cannot respond to pressure fluctuations as quickly, resulting in a loss of some of the signal. In future monitoring, the hydrophone should be used as close to the pier being imploded as feasible without overloading the hydrophone but sampled at the higher rate. It is expected that at distances greater than 500 feet there will reach a distance where the high sample rate is not necessary to capture the signal accurately. This distance could not be determined at this time; although, it is suspected to occur around 1,000 feet, based on the results shown in Figure 56. This distance should be carefully considered and properly determined for future monitoring programs.



Note:
Pressure waveform at 500 feet from the east for a hydrophone sampled at both 2,000,000 and 96,000 samples/second.

Figure 62. Pressure Waveform at 500 feet from the East (2)

6.2.5.3. SUMMARY COMPARISON OF MODELED AND MEASURED POTENTIAL IMPACT CRITERIA

Based on the measured data from the Demonstration Project, the resulting distances to fish and marine mammal cSEL threshold criteria were less than the distances that were modeled in advance. Peak pressure level from the blast, however, was slightly greater than anticipated and the measured levels for peak pressure show a greater potential impact area for that criterion than modeled. The following figures provide a visual reference of the information shared in the tables and text found in previous sections of this report as a helpful reference to gauge where potential impact areas were during the Demonstration Project.

Figure 63 shows radial isopleths out to the modeled potential impact areas for fish as determined by the FHWG interim criteria for fish, i.e., the 206dB peak pressure, 187 dB cSEL for fish greater than 2g and 183dB cSEL for fish less than 2g. Figure 64 shows radial isopleths out to the Demonstration Project's measured potential impact area for those same fish criteria

Figure 63. Modeled Isopleths to Fish Threshold Criteria

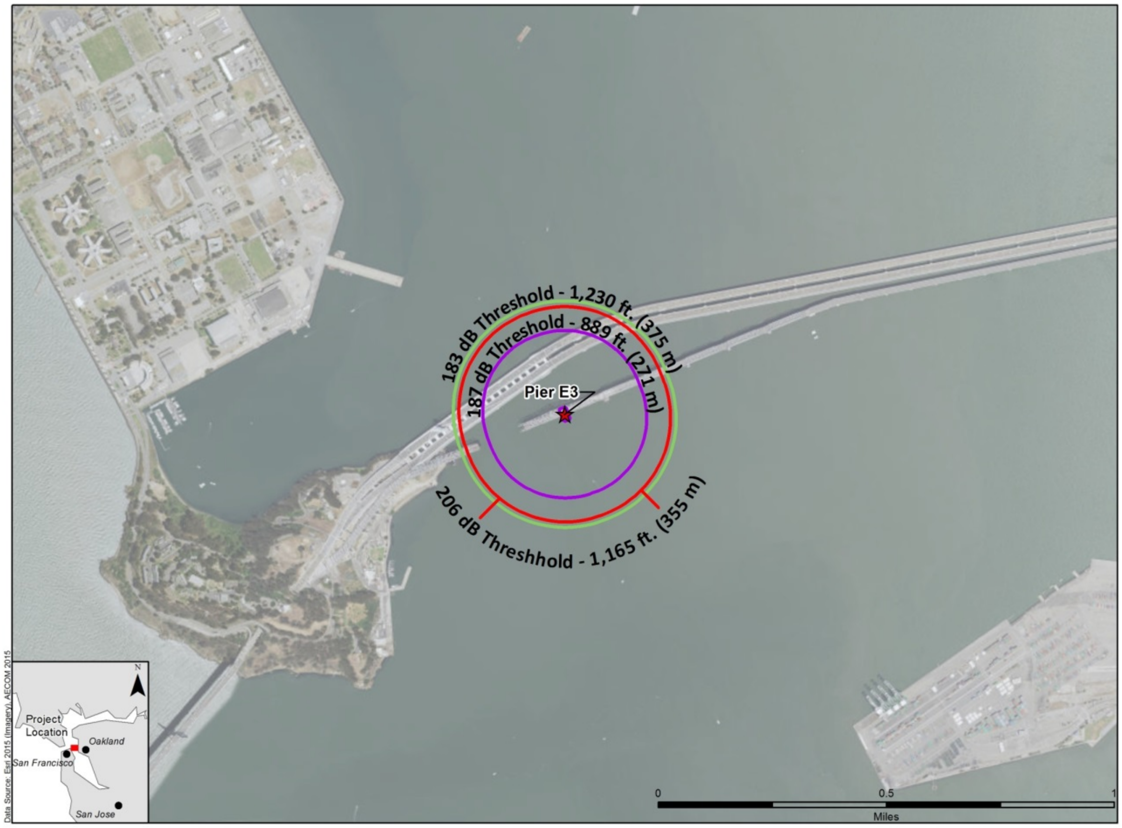


Figure 64. Measured Isopleths to Fish Threshold Criteria

Figure 65 shows radial isopleths out to the modeled potential impact area for pinniped PTS, TTS and behavioral response threshold criteria. Figure 66 shows radial isopleths out to the Demonstration Project's measured potential impact area for pinniped PTS, TTS and behavioral response threshold criteria. Figure 67 shows the shows radial isopleths out to the modeled potential impact area for high frequency porpoise PTS, TTS and behavioral response threshold criteria. Figure 68 shows radial isopleths out to the Demonstration Project's measured threshold criteria for high frequency porpoise.

Figure 65. Modeled Isopleths to Pinniped Threshold Criteria

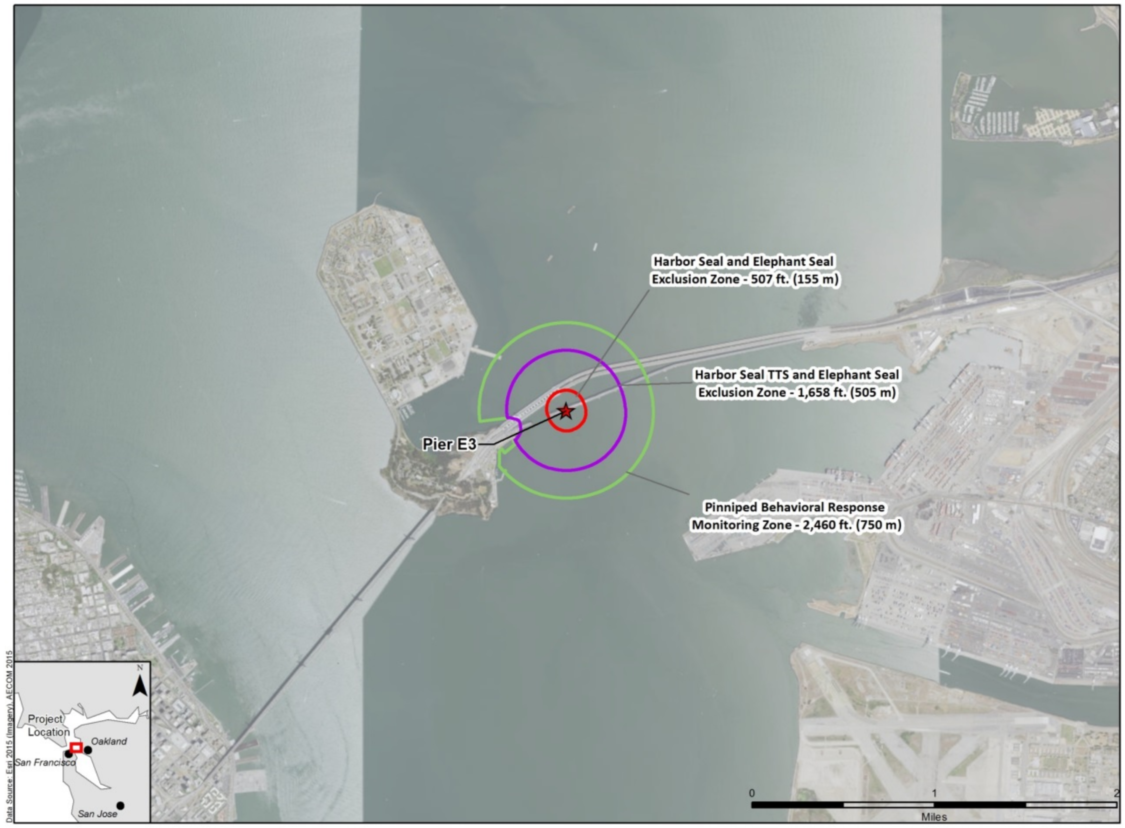


Figure 66. Measured Isopleths to Pinniped Threshold Criteria

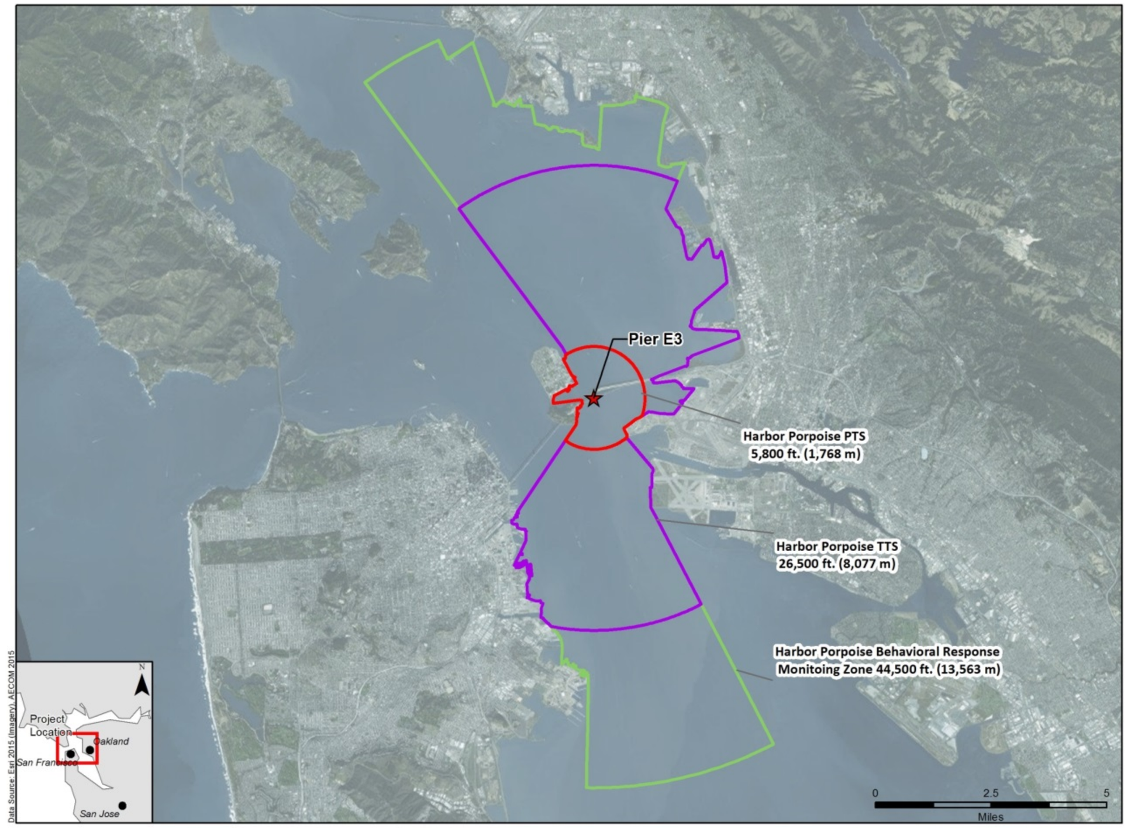


Figure 67. Modeled Isopleths to High Frequency Porpoise Threshold Criteria

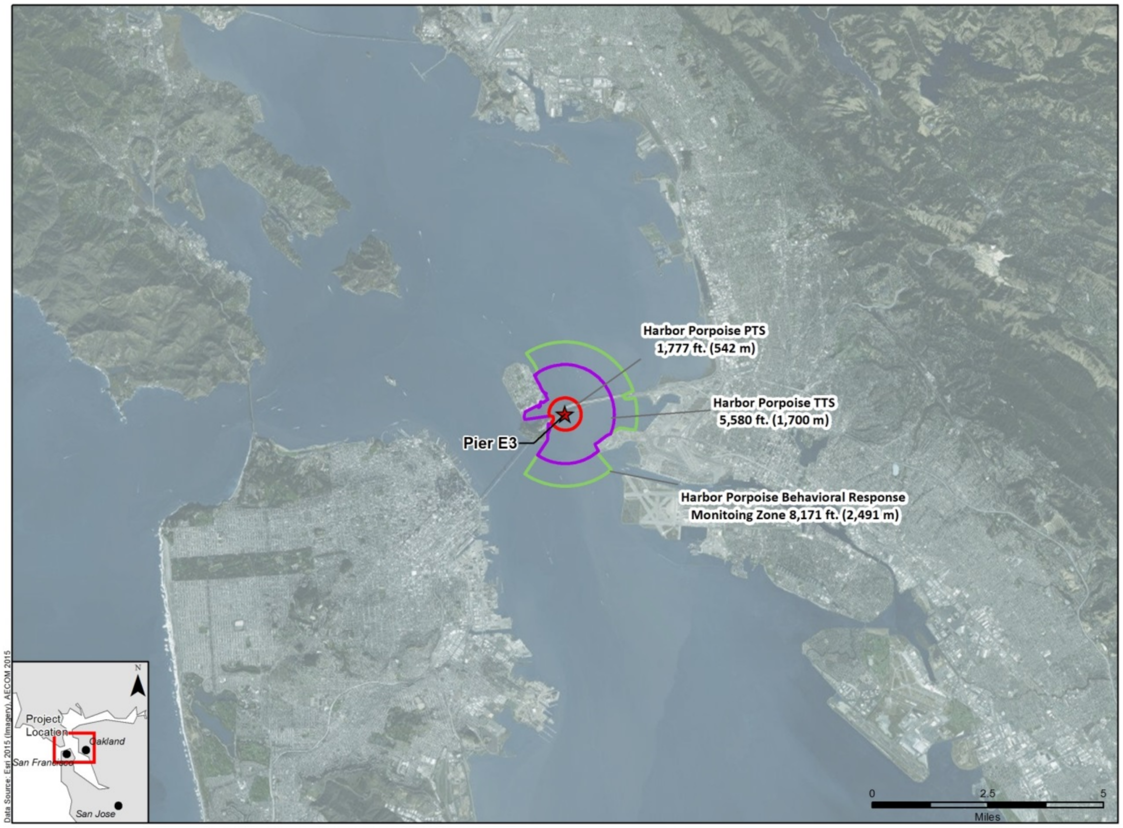


Figure 68. Measured Isopleths to High Frequency Porpoise Threshold Criteria

6.3. Water Quality

Between October 28, 2015 and November 14, 2015, sediment sampling, dynamic plume mapping, and water quality grab sampling were used to verify the potential water quality impacts that were documented in the WQS (Table 21). Prior to the implosion, baseline sediment samples and water quality grab samples were collected. Immediately after the implosion, on November 14, 2015, the plume was continuously monitored until water quality returned to baseline conditions in approximately four to five hours.

Five stationary water quality loggers were placed in ESAs along the eastern sides of YBI and Treasure Island and recorded water quality parameters throughout the day of implosion and continued for 48 hours after implosion (Figure 69). Post-implosion sediment sampling was conducted on January 8, 2016.

Figure 69. Location of Eelgrass Monitoring Buoys

Table 21. Samples Collected October 28, 2015 to January, 2016

Sample Media	Sample Type	Number of Samples	Constituents Analyzed
Sediment	Grab	Twelve	pH, sediment toxicity, trace metals (Pb, Cu, Ni, Zn, Cr, Ag, Cd)
Water	Grab	Twenty	Dissolved and total metals (Pb, Cu, Ni, Zn, Cr, Ag, Cd), SSC, DO, temperature, salinity, conductivity, turbidity, pH
Water	Continuous	~20,000 data records	turbidity, pH, conductivity, temperature, DO, salinity

6.3.1. Pre-Implosion and Post-Implosion Sediment Sampling

Sediment sampling was conducted two weeks prior to the implosion event to assess the impact on sediment chemistry and toxicity at the sediment/water interface. Three locations were sampled pre-implosion in the immediate vicinity of Pier E3 (near-field) and three locations were sampled in the plume area predicted by modeling (far-field).

Pre-implosion sediment sampling indicated some toxic effect on mussel larvae at the sediment/water interface. This is typical for San Francisco Bay and comparable to results from the San Francisco Bay Regional Monitoring Program.

Post-implosion sediment sampling was conducted on January 8, 2016. Sampling was conducted at the same near-field sampling locations sampled pre-implosion. Far-field sampling locations were modified based on the actual path of the plume. Post-implosion sediment laboratory results are included in the final Pier E3 Water Quality Monitoring Results report, submitted under separate cover. ~~expected in late January or early February.~~

6.3.2. Pre-Implosion Water Quality Sampling

Pre-implosion water quality grab sampling was conducted on October 31, 2015 measuring water quality parameters in the San Francisco Bay using three different 5-L Niskin bottle samplers. This was done to establish baseline water quality values. Each sampler was triggered at a different water column depth (top, middle, and bottom). The Niskin bottles were attached to the cage of a conductivity-temperature-depth (CTD) water column profiler which measured turbidity, pH, and DO at the three different water column depths.

A sample was collected in each Niskin bottle. Each sample was analyzed for DO, salinity, conductance, turbidity, and pH in the field. A portion of the sample was filtered in the field. The filtered and unfiltered samples were placed in clean pre-labeled bottles, capped, stored on ice and shipped to an analytical laboratory. Filters used during field sampling were disposed of as non-hazardous solid waste.

Turbidity, DO, and pH that were measured on October 31 were relatively unstratified. Turbidity varied between approximately 7 and 9 NTU; DO held steady at approximately 6.6 milligrams per liter; and, pH remained at approximately 7.95. Metals concentrations are still being analyzed and results are expected to be available at a later date.

6.3.3. Post-Implosion Water Quality Sampling

A set of five post-implosion water quality grab samples and CTD casts were taken on November 14, 2015 (Figure 70). Post-implosion grab sampling and CTD casts were conducted in the same manner as those collected prior to implosion. See Table 22 for a summary of CTD casts.

Table 22. November 14, 2015 CTD Casts

Cast	Date	pH	Turbidity (NTU)	Notes
Baseline	October 31	7.95	7 to 9	
Cast 1	November 14 Time: 7:40 a.m.	8.0	20.5 to 22.7	Bubble curtain influenced readings; relatively consistent turbidity throughout water column; pH readings within baseline.
Cast 2	November 14 Time: 8:20 a.m.	8.3 to 8.7	16 to 21	Bubble curtain effects attenuated; measured at centroid of plume
Cast 3	November 14 Time: 8:55 a.m.	8.0	16.5 to 25	Turbidity greater at Bay floor
Cast 4	November 14 Time: 9:33 a.m.	8.0 to 8.1	16.5 to 20	
Cast 5	November 14 Time: 11:25 a.m.	8.05	20 to 22	

Figure 70. Water Quality Sampling Locations

After the implosion, the first CTD cast and grab samples (Cast 1) were taken at 7:40 AM. However, the sampling boat did not move into the plume to collect the first cast. This was done for safety reasons and to minimize impacts on other post-implosion construction and sampling activities that had been given priority over water quality sampling.

At the time of Cast 1, the bubble curtain was still operating. During the time between implosion and Cast 1, the current had moved north from Pier E3. Because of this, the first cast was collected in a water mass heavily influenced by the bubble curtain, but was outside the influence of the plume. The current later shifted to the south. The second cast, taken at location south of Pier E3 at 8:18 AM, was near the centroid of the plume.

Cast 2, measured within the post implosion plume, had an elevated pH of ~8.5 and a reduced turbidity reading suggesting lessened turbidity effects of the bubble curtain. Salinity was still stratified, and the slight DO depression of bottom waters was still evident. Cast 3 indicated a slower rate of change in water column concentrations. Cast 4 and Cast 5 documented a return of water quality to background conditions.

~~Metals concentrations and DO measurements are still being analyzed and expected to be available at a later date.~~ Water quality results for metals and DO are summarized in the final water quality report, submitted under separate cover.

6.3.4. Dynamic Plume Mapping

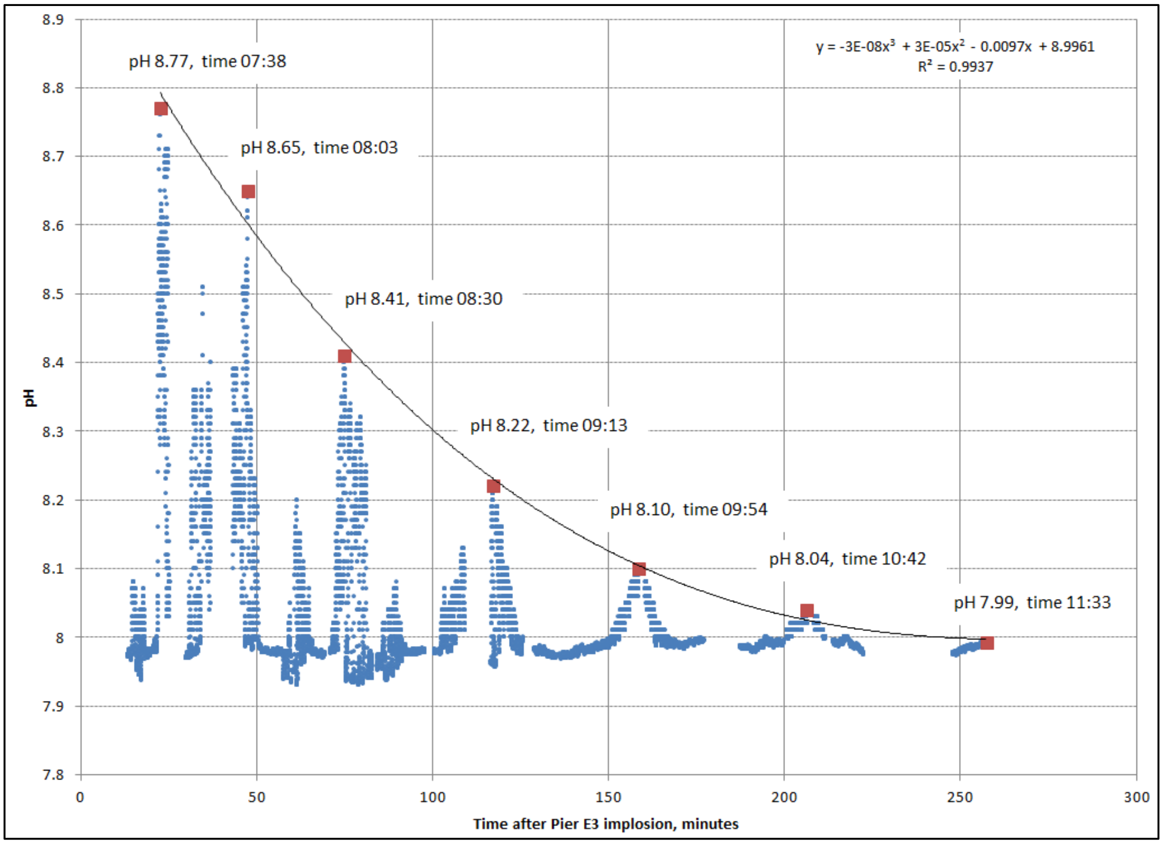
A research vessel specially outfitted for three-dimensional subsurface plume tracking was used. Operation of this vessel involved lowering and raising instrumentation through the water column while the vessel was under way. The vessel travelled transversely across the plume at least six times while the plume moved and dispersed with the tide and current.

A second vessel deployed current drogues to aid the dynamic plume mapping team track the extent of the plume.

A review of dynamic plume mapping of turbidity confirms the grab sampling results. It is difficult to discern any turbidity effect of the implosion that stands out above San Francisco Bay water ambient conditions or the turbidity effect of the bubble curtain.

Figure 71 shows the pH measured by the plume mapping boat versus minutes after the implosion, which occurred at approximately 7:17 AM. The decay curve of pH over time tracks the dispersion of the plume following the moment of implosion. The third order polynomial decay curve is consistent with expected dispersion of water properties in a fast moving current. Using this decay curve, the pH near the centroid of the plume just after the implosion would have been approximately 9.0 standard units.

The decay curve shows that the pH returned to within 0.5 units of baseline (pH 8.0) in approximately 1 hour, and returned to baseline within 4 hours. The return to baseline was longer than the 2 hours estimated in the WQS. The immediate magnitude of the impact near Pier E3 was consistent with the predictions of the WQS.



Note:
Taken at approximately 7:17 a.m. on November 14, 2015.

Figure 71. Preliminary Results of Dynamic Plume Mapping of pH following Implosion of Pier E3

The results indicate that the maximum pH of 9.0 standard units near Pier E3 just after implosion is consistent with a model based on pH primarily being affected by explosive residue, rather than release of calcium oxide from structural PCC. The 5 percent-of-the-Pier-E3-PCC-mass assumption was clearly overly conservative. The pH effects were somewhat greater than the "explosives only" prediction of pH 8.7. The measured outcomes versus the predicted can be used in future water quality studies to calibrate the true effect of PCC. It is much more likely that a fraction of a percent (i.e., much less than 5 percent) of the total mass of the concrete structure will contribute pH-increasing calcium oxide during future implosion events.

6.3.5. Environmentally Sensitive Areas Monitoring

Monitoring was conducted on the day of implosion to confirm that the plume did not affect water quality in the vicinity of environmentally sensitive areas, namely eelgrass beds along the YBI coast and along the eastern edge of Treasure Island (Figure 69). Buoys, left in place for 48 hours after the implosion, continuously monitored mid-depth turbidity, pH, dissolved oxygen, temperature, and conductivity. The implosion did not appear to create a measureable impact on parameters measured by the buoys. This indicated that water quality measured at the eelgrass beds appeared to remain within background levels for the entire 48-hour post-implosion measurement period.

6.4. Fish

6.4.1. Caged Fish

Of 491 caged fish subjected to exposure to the implosion, 37 fish were impaired and five fish died. Injuries detected during the necropsy process were inconsistent with barotrauma and are more indicative of handling stress for the impaired and dead fish as well as the live fish that were subjected to necropsies. There was no pattern to the incidence of injury or mortality within the cages, further suggesting the finding that injuries were unrelated to blast exposure.

Twelve cages, each with about 40 hatchery-reared juvenile late fall-run Chinook salmon, were deployed in the Bay at known distances from Pier E3 before the implosion. A control cage was deployed 2,550 feet from the pier, but was retrieved from the Bay just before the implosion. Following the implosion, the eleven remaining cages were retrieved from the Bay and were taken back to Clipper Cove. The salmon in each cage were assessed as normal, impaired or dead. A subset of the normal fish and all the impaired and dead fish were necropsied. Following the implosion, two experienced fishery biologists inspected each cage and classified the fish. Normal swimming fish appeared healthy, swam in an upright position holding their bodies parallel to the surface and responding to stimuli. Impaired fish were disoriented, swam weakly, often with their heads up and tails down and often would turn on their sides or rest on the bottom of the cage. Impaired swimming fish were slow to respond or did not respond to stimuli (e.g., did not attempt to avoid the dip net). Fish that showed no evidence of moving their gill covers were classified as dead.

Normal swimming fish were by far the most common condition found in all the cages following the implosion, ranging from about 82 percent to 100 percent of each cage. Figure 72 shows the percent of normal fish from each cage deployed for the implosion. The cage designation is typically the deployment distance from the southwest face of Pier E3 in feet. The exception is that Cage 4000 was deployed at 3,315 feet to avoid the shipping channel to the Port of Oakland.

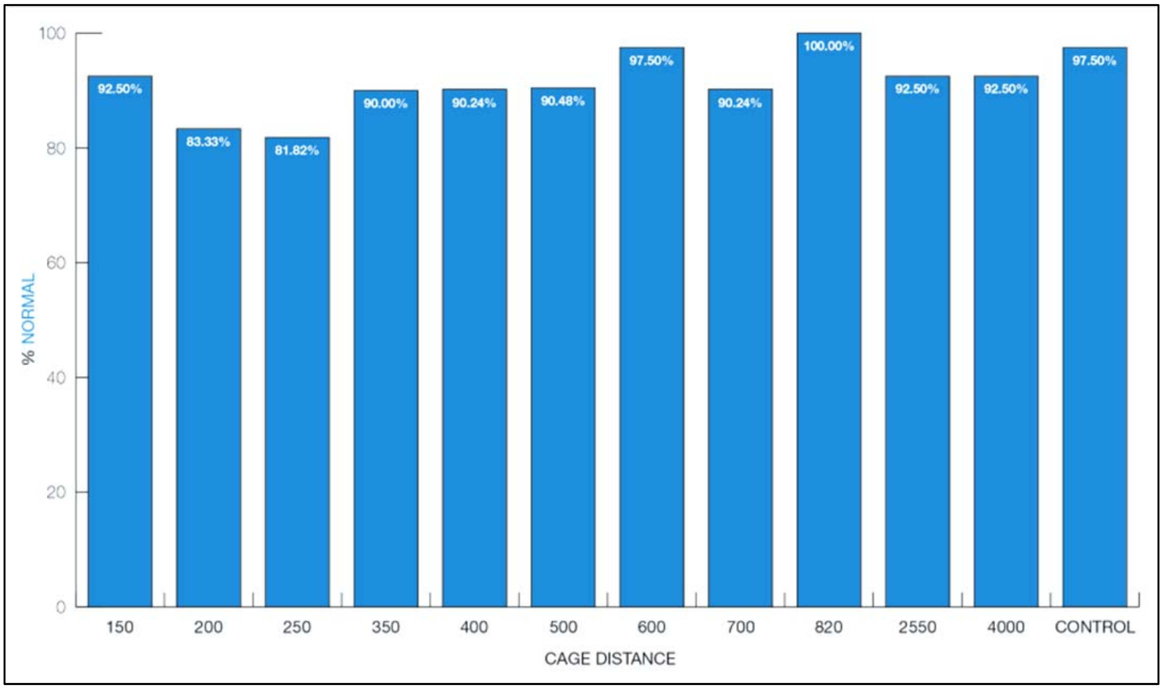


Figure 72. Percent of Normal Fish from Each Cage Deployed for the Pier E3 Implosion

Impaired fish were distributed randomly throughout the cages. A slightly higher number of impaired fish occurred in cages 200 and 250 (seven fish in each). Both of those cages had slightly higher counts of deployed fish (42 and 44, respectively). The pattern shows a fairly consistent rate of impairment across the spectrum of exposure (Figure 73). Only five fish were classified as dead. All the dead fish occurred between 250 and 700 feet from Pier E3. Figure 73 shows the percent of impaired fish (orange) and dead fish (gray) in each cage by distance from Pier E3.

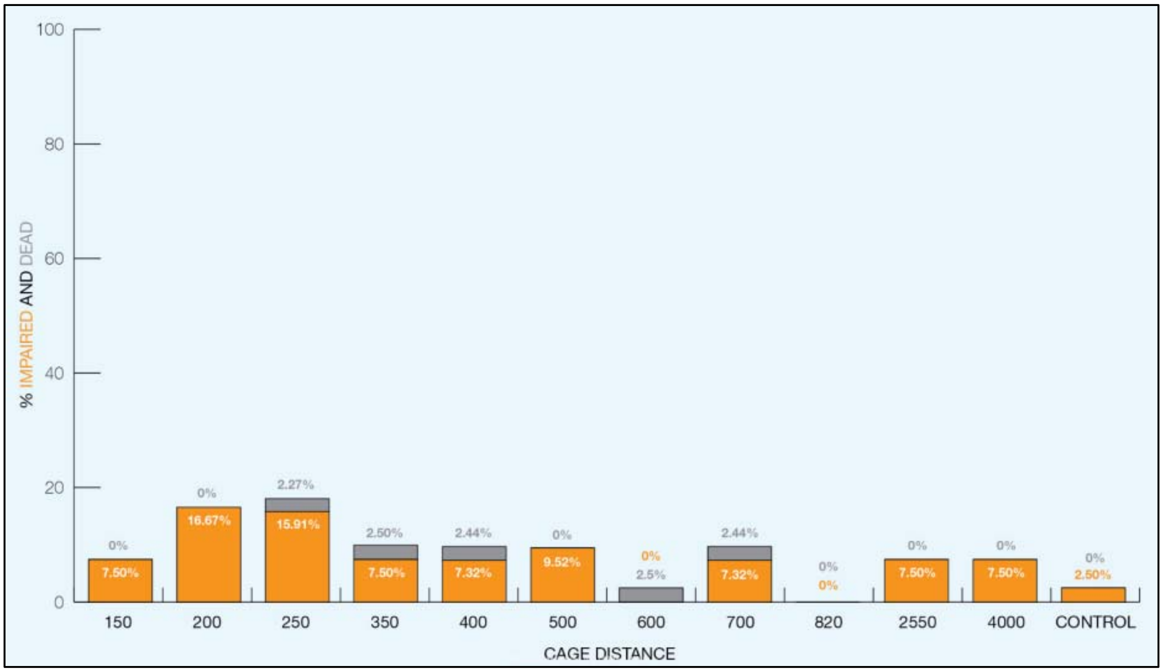


Figure 73. Percent of Impaired Fish (orange) and Dead Fish (gray) in Each Cage by Distance from Pier E3

Hydroacoustic monitoring results were used to determine received peak and cSEL sound pressure levels at each of the caged fish locations (Table 23).

Table 23. Sound Pressure Levels at Caged Fish Locations

Cage ID	Distance	Peak	cSEL
150	150 feet	227 dB	209 dB
200	200 feet	224 dB	205 dB
250	250 feet	222 dB	203 dB
350	350 feet	218 dB	198 dB
400	400 feet	217 dB	197 dB
500	500 feet	215 dB	194 dB
600	600 feet	213 dB	192 dB
700	700 feet	211 dB	190 dB
820	820 feet	210 dB	188 dB
2550	2550 feet	198 dB	174 dB
4000	3315 feet	195 dB	171 dB

All cages had similar soak times (the amount of time the cage was deployed in the Bay), ranging from 1 hour and 38 minutes to 2 hours and 14 minutes. Cage confinement times (the amount of time the fish were confined inside the cage) ranged from 3 hours and 30 minutes to 6 hours and 6 minutes. These differences primarily were related to the 3-hour processing time needed for all the fish, following the implosion.

Caged Chinook salmon subjected to necropsy after the implosion did not have any lesions related to barotrauma. The range of lesions was similar in controls, fish caged nearest to the implosion, and fish caged further from the implosion.

After the implosion, the pathology team conducted necropsies on 90 fish, including all fish that had died (n = 5), all fish that were impaired (n = 37), and four groups of 12 randomly selected, normally swimming fish from the: 1) un-deployed net pen controls; 2) caged fish deployed in the control cage; 3) caged fish deployed at 150 feet; and 4) caged fish deployed at 200 feet. All necropsies were completed within 3 hours of the implosion. The swim bladder was assessed on every fish necropsied. All swim bladders were intact and fully inflated (= score of 0). Among the 90 fish subjected to necropsy, only two fish had internal hemorrhaging. The two fish that showed signs of hemorrhaging, one on the ventral surface of the swim bladder and one on the surface of the intestinal mesentaries - were deployed at 350 and 3,315 feet respectively. Because the affected fish were not in the closest cages during the implosion, the lesions likely were the consequence of trauma sustained during handling (ESA 2015).

6.4.2. Sonar Fishery Assessment

On October 29 and 30, 2015, acoustic data were collected along a total of 16 transects, with four transects north and four south of the original Bay Bridge Pier E3 surveyed on each day. A total transect length of 4.24 miles (6.8 kilometers [km]) was sampled on October 29, and 4.5 miles (7.2 km) was sampled on October 30. The approximate total area of water represented by acoustic surveys was 43.8 hectare (ha) north of Pier E3, and 49.2 ha south of Pier E3. Water conditions were calm on both survey dates, with surface water temperature of 20°C and salinity of 30 parts per trillion (ppt).

For both days combined, the target strength distributions for tracked fish were similar between the north and south transects. The conversion of target strength to length indicated a mode of approximately 60 millimeter (mm). Fish greater than 100 mm represented less than 7 percent of the total for the north transects, and less than 4 percent of the total for the south transects. For each 25 mm size class, tracked fish density was typically higher along the south transects. The highest estimated mean density among all size classes was 8.7 fish/1,000 cubic meters for the 25 to 50 mm class along the south transects.

The mean density of all tracked fish was significantly higher for the south transects compared to the north (two sample t-test, α=0.05, P value=0.008), and the overall mean density for both regions combined was 12.5 fish/1000 cubic meters. The overall mean density of schooled fish within the full acoustic volume sampled was not significantly different between the north and south transects (two sample t-test, α=0.05, P value=0.390), and the mean schooled fish density for both regions combined was 75.6 fish/1000 cubic meters. For the north and south transects combined, the total tracked and schooled fish density estimate was 88.1 fish/1000 cubic meters, and there was no significant difference between mean density between the north and south regions (two sample t-test, α=0.05, p=0.536).

6.4.3. Bird Predation Monitoring

Bird predation is defined as birds attempting to prey or feed on other organisms. Monitoring of predation activity consisted of counting bird strikes on the water surface. A bird strike on the water surface was not counted as a fish kill or fish consumption. In fact, many observations of bird strikes noted the bird retrieved nothing, retrieved pieces of the blasting mat, or retrieved other material displaced by the blast. This monitoring requirement was conducted in accordance with Section 1.3.7, Avoidance and Minimization Measure No. 4 of the SFOBB Pier E3 Demonstration Project BO, issued by NMFS on August 27, 2015.

Immediately following the blast there was a temporary lull in bird activity. By 7:20 AM, birds (primarily gull species with brown pelicans and cormorants also being observed) attracted to the area began to dive and strike at the water surface South of the implosion. Again, it should be noted that during observations, large numbers of birds were observed striking at a variety of items, including debris and benthic organisms. Initial bird predation activity was concentrated in an area approximately 100 feet to 1,000 feet from the location of the former pier. Bird strikes were counted regardless of what the bird's apparent prey target was. Specific prey data was not collected. Birds were observed striking at floating organic debris, benthic organisms that were brought to the surface by the blast and moribund or perished fish floating at or near the surface of the water.

Following the implosion, boat-based bird-predation monitors were located approximately 1,500 feet southeast of the imploded pier. The monitoring boat tracked bird predation activities occurring south of the imploded pier, and followed these activities in a generally southwestern direction following the current. Boat-based monitors observed a rapid escalation in bird predation activity to more than 100 strikes per minute during the first 15 minutes following the blast (7:17 AM to 7:32 AM). Birds were observed striking at floating organic debris, benthic organisms that were brought to the surface by the blast and moribund or perished fish floating at or near the surface of the water. Bird predation decreased to approximately 50 strikes per minute between 7:32 AM and 7:38 AM and to approximately 25 strikes per minute between 07:38 AM and 08:05 AM. Predation gradually tapered off after 8:05 AM until birds were observed floating at the water surface, foraging on the occasional fish by the end of the monitoring period (8:17 AM). Bird predation activity and debris from the blast appeared to follow the tide in a southerly direction from Pier E3, dispersing to the southeast and southwest in the hour following the implosion.

The bike-path based monitor focused on bird predation observations immediately southwest of Pier E3. Observations recorded at this location show the same trend observed from the monitoring boat of high levels of predation activity immediately following the blast that taper off around 8:00 AM. At this location, bird predation activity approached approximately 25 strikes per minute between 7:21 AM and 7:26 AM, before diminishing to between 4 and 16 strikes per minute between 7:27 AM and 7:53 AM. After 7:53 AM, bird predation activity in this location tapered off until birds were only observed floating at the water surface until the end of the monitoring period (8:17 AM).

Between 7:17 AM and 8:17 AM, the three monitors stationed in the boat collected any fish found floating at the water surface. No listed fish species were observed. Only four fish were collected: two brown rockfish (*Sebastes auriculatus*), one black surfperch (*Embiotoca jacksoni*), and one northern anchovy (*Engraulis mordax*). All four individuals were moribund, found at the surface visibly stunned. These fish were necropsied by Moss Landing Marine Laboratory (MLML) staff that was on site conducting the trawling effort and found to have injuries related to the implosion.

6.4.4. Trawl Sampling

A total of 203 fish, comprising 15 species were collected in 13 tows on October 31, 2015, as a pre-implosion or baseline assessment of the fish assemblage composition and relative abundance in the study area (Table 24) under a Scientific Collecting Permit issued to Dr. Scott Hamilton of Moss Landing Marine Lab. Trawls captured 151 Speckled sanddabs, which were primarily juveniles. The next most abundant species were California halibut (14), plainfin midshipman (10), and brown rockfish (9). These species were also primarily composed of juvenile-size classes. No federal or state-threatened or endangered fishes were collected, and 89.5 percent of trawl-caught fish were alive and uninjured. The only pelagic (open water) species collected was northern anchovy. Brown rockfish and shiner surfperch are structure-oriented fishes, while the rest of the collected fish species are bottom-oriented. A total of 1,229 fish comprising nine species (Table 25) was collected in 14 tows between 7:24 AM and 8:34 AM on November 14, 2015 in accordance with the ITP issued by CDFW. The trawling mostly occurred between 2,500 and 4,000 feet from the pier and began immediately after the implosion was over. Trawls captured 1,073 juvenile

Table 24. Summary of fish catches on October 31, 2015

Species	Midwater trawl (north) *n* = 3 trawls		Otter trawl (north) *n* = 5 trawls		Otter trawl (south) *n* = 5 trawls		Total Alive	Total dead
	Number Alive	Number Dead	Number Alive	Number Dead	Number Alive	Number Dead		
Bay Goby					2	0	2	0
Brown Rockfish			1	1	8	0	9	1
California Halibut			2	0	12	0	14	0
California Tonguefish					1	0	1	0
Chameleon Goby					1	0	1	0
Diamond Turbot					2	0	2	0
English Sole					1	0	1	0
Guitarfish			1	0	1	0	2	0
Lizardfish	1	0			1	1	2	1
Northern Anchovy					2	2	2	2
Plainfin Midshipman					10	0	10	0
Shiner Surfperch					1	0	1	0
Speckled Sanddab					131	17	131	17
Unidentified Goby					2	0	2	0
Unidentified Sculpin					2	0	2	0
Grand Total	1	0	4	1	177	20	182	21

Note:
Summary of catches of fishes on the practice day (October 31, 2015) using one midwater trawl and two bottom (otter) trawls to the north and south of Pier E3. Of total trawl-caught fish, 11.5 percent were dead because of damage from the trawl gear.

Table 25. Summary of fish catches on November 14, 2015

Species	Midwater trawl (north) *n* = 4 trawls		Otter trawl (north) *n* = 4 trawls		Otter trawl (south) *n* = 6 trawls		Total Alive	Total dead
	Number alive	Number Dead	Number alive	Number Dead	Number alive	Number Dead		
Brown Rockfish	2	0	2	0	13	0	17	0
California Halibut	2	0			19	0	21	0
California Tonguefish	1	0			1	0	2	0
English Sole					1	0	1	0
Northern Anchovy	978	61			26	8	1004	69
Pipefish					1	0	1	0
Plainfin Midshipman					13	0	13	0
Speckled Sanddab	6	0	2	0	90	2	98	2
Staghorn Sculpin					1	0	1	0
Grand Total	989	61	4	0	165	10	1158	71

Note:
Summary of catches of fishes on the demolition day (November 14, 2015) using one midwater trawl and two bottom (otter) trawls to the north and south of Pier E3. Of the total trawl-caught fish on demolition day, 5.8 percent were dead, most likely because of damage caused from the trawl gear.

anchovies. The next most abundant species captured by the trawls included speckled sanddabs (100), California halibut (21), and brown rockfish (17). All fishes caught were juveniles. No federal or state-threatened or endangered fishes were collected and 94.2 percent of the trawl-caught fish were alive and uninjured. Again, the only pelagic species collected was Northern anchovy. Pipefish are typically associated with beds of underwater vegetation.

No federal or State-threatened or endangered fishes were collected by any of the trawls. ~~Necropsies were conducted on 37 injured fish caught by trawls. A small number of trawl-caught fish had injuries that could have been attributed to the implosion or to the trawl gear.~~

For the purposes of this effort, moribund fish were considered to be perished. A moribund fish is not technically dead, but is unable to swim or maintain an upright position in the water column, and thus would almost certainly result in a death if more time was allowed to pass. Moribund and dead fish were lumped together into the same data class—the distinction between the two was not recorded. A total of 71 out of 1,158 fish captured in the trawls were moribund or dead. Necropsies were performed on 37 of those 71. The rest of the fish were noted as having either no visible injuries (22) or only light hemorrhaging (17). This light hemorrhaging/damage was so minor that it could be attributed to the blast, caused by the trawling nets, or caused by handling. Based on how far the majority of these fish were collected from the pier, their injuries were most likely the result of the trawling net and handling, not the blast.

6.5. Birds

On November 14, bird monitors were in position by 5:30AM; the lead avian monitor was positioned on the new SFOBB east span bike path, and three monitors were positioned in a boat. The monitor positioned on the bike path was located directly northwest of Pier E3. The boat-based monitors were located directly south of Pier E3, near the boundary of the 1,500 foot MTSZ. Between 5:30AM and approximately 6:30AM, visibility was limited because of the lack of daylight. At that time, most of the visible bird activity was concentrated around the anchored barges, where multiple species of gulls were observed feeding on fish at the surface. On two occasions (6:00 AM and 6:30 AM), a laser with a 30 milliwatt green beam with a 532 nanometer wavelength was used from the bike path to flush birds from the vicinity of the Pier E3 blast mat. On the first occasion, an unidentified gull flushed immediately and departed to the east; on the second occasion, ambient light conditions had reduced the visibility of the laser enough that the operator was unable to track the laser's path and the targeted bird did not appear to respond to the laser light aimed in their direction.

As daylight increased visibility leading up to the blast (6:35 AM to 7:16 AM), approximately 100 birds were seen flying in different directions through the general project area; typical species observed included double-crested cormorant (*Phalacrocorax auritus*), Canada geese (*Branta canadensis*), brown pelican (*Pelecanus occidentalis*), osprey (*Pandion haliaetus*), and multiple species of gulls.

As the time of the implosion approached, boat-based hazing of the area immediately outside the 500-foot Avian Watch Zone was determined to be unnecessary because of the absence of birds. As stated above, birds observed prior to the blast were primarily limited to fly-overs, with instances of feeding on the surface earlier in the morning. The boat-based avian monitors did not observe birds at the water's surface or diving into the water column in or near the 500-foot Avian Watch Zone immediately prior to the implosion of Pier E3.

The propane-powered bird cannons were fired at 7:16 AM, one minute prior to the implosion of Pier E3. Three western gulls were observed flushing from the area at the time of the sound cannon. The gulls appeared to be located near the support barge to the east of the Pier E3 and left the area. Immediately following the implosion (7:17 AM), there was a temporary lull in bird activity. By 7:20 AM, birds (primarily gull species [brown pelicans and cormorants also observed]) attracted to the area began to dive and strike floating debris and dead and stunned fish immediately south of the implosion site. Avian monitors observed hundreds of birds fly over and dive into the water column within an approximate 1,000-foot radius of the imploded p in the first 15 minutes following the implosion. Bird activity gradually tapered off in the hour following the blast, and monitoring was concluded at 8:00 AM Monitoring results of bird predation is described in greater detail in the Bird Predation Monitoring results section. No injured or dead birds were found by avian monitors following the implosion of Pier E3.

<u>As described in Section 4.1.2.1 of this report, the Department used the 202dB cSEL criteria to calculate the area of potential auditory injury to birds exposed to the in-water impulse sound generated by the implosion of Pier E3. The Department calculated a 500-foot distance to the 202 dB cSEL threshold based on advance modeling. Based on the Demonstration Project's hydroacoustic monitoring results, the 202 dB cSEL threshold was measured at approximately 300 feet, resulting in a 200-foot reduction in the distance to the potential auditory injury threshold from the modeled to the measured distance.</u>

These results indicate that the Department's calculated distance for potential auditory injury to birds was conservative, and slightly higher than the measured cSEL levels. Hydroacoustic monitoring results are presented in Section 6.2 and measured cSEL values for all of the monitoring locations are shown in Figure 56.

6.6. Marine Mammals

Prior to the implosion of Pier E3, only one marine mammal, a harbor seal, was observed by any of the marine mammal monitors. The seal was observed at approximately 6:45AM and approximately 4,500 feet north of Pier E3 by the marine mammal observer positioned on Treasure Island. The animal was within the Level B Harassment – TTS monitoring zone, as specified in the Incidental Harassment Authorization, however, it dove into the water shortly after being seen and then was not seen again for over 30 minutes prior to the implosion. This did not result in any delay of the implosion. No other animals were observed prior to the blast.

Following implosion, 60 minutes of monitoring was conducted for marine mammals. During this time, several harbor seals and California sea lions were observed in the surrounding area, but none exhibited any evidence of blast-related injury or impairment. Two hours after the implosion and for three days following (November 15 through 17), surveys were conducted of haul out sites in the vicinity of the pier to locate any potentially impaired or injured animals. Surveyed areas included Treasure Island, Yerba Buena Island, Emeryville Crescent, Oakland Harbor, and Oakland Touchdown. No potentially injured animals were identified. It was also confirmed with the Marine Mammal Center, a local wildlife rescue organization and the official NOAA-designated marine mammal stranding center for northern California, that no animals with blast-related injuries were reported.

6.7. Traffic

6.7.1. San Francisco-Oakland Bay Bridge

To minimize distraction to the public a full traffic stop in both directions of the SFOBB was executed for the implosion. Twenty California Highway Patrol (CHP) vehicles and associated personnel were used for this detail. The eastbound onramp at the tunnel on YBI was also closed. In addition, to meet the request of the San Francisco Fire Department for emergency response to the island the eastbound number 1 lane (farthest left lane) was closed from San Francisco to YBI. The lane closure was installed 60 minutes before the planned implosion. The westbound traffic block began 10 minutes before the planned implosion. The eastbound traffic block began 10 minutes before the planned implosion. Traffic in both directions was held until the implosion occurred. Traffic was released in both directions after the all-clear safety signal was given and the eastbound onramp was reopened. Heavy traffic conditions cleared within 10 minutes after the lanes were reopened. The eastbound number 1 lane closure was removed within 30 minutes after the implosion.

6.7.2. Bay Area Rapid Transit

The Bay Area Rapid Transit (BART) Transbay tube (Figure 74) is a 3.6-mile-long underwater rail tunnel which carries four Transbay rail lines under the Bay between the cities of San Francisco and Oakland. At its nearest point the tube is approximately 3,000 feet to the south of Pier E3. Prior to the implosion, the Department collaborated with BART officials and provided data and calculations indicating the expected impact of the implosion on the tube. As a precaution, BART officials chose to shut the tube down during the implosion event. Trains were held up at each end of the tube on the same time schedule as the traffic blocks on the SFOBB noted above.

Blast vibration monitoring was conducted on the tube gallery wall during the implosion. Four velocity geophones and one accelerometer were affixed on brackets to the North wall of the central gallery near door 36 at mile post 4.78. The geophones were mounted on separate brackets approximately 6 feet apart on the tube gallery wall and the accelerometer was affixed to a bracket below the geophones.

Data acquisition systems included three White Seismology blasting-type seismographs, one NOMIS seismograph and an HBM eDAQ Lite. Seismograph operating parameters are provided in Table 26. Wall motions using a PCB Piezotronics 356A34 triaxial accelerometer were recorded using the eDAQ Lite at a sample rate of 100 kHz. The trigger level was set to 0.1 g.

Before the blast, all recording systems were used to record vibrations from passing trains starting at 6:02 AM. All five systems were operable and recorded wall vibrations from several trains. The blast occurred at 7:17 AM and triggered all four seismograph systems. However, the accelerometer system did not trigger because of the very low frequency of the blast motions on the wall (less than 4.1 Hz). All systems remained on operating mode after the blast to record wall vibrations during the passing of several trains. All five systems were confirmed to be in operating condition.

Table 26 provides a summary of the measurements from each of the 4 seismograph monitoring systems. The highest wall velocity recorded during the blast was 0.061 inch per second (in/s). This was recorded with the NOMIS system sampling at the highest sample rate of 16,384 samples per second. The high sampling rate resulted in a peak frequency of 115.3 Hz. Sample rates of 4,098 and less used for the other systems produced lower peaks at peak frequencies less than 4.1 Hz. It is apparent that lower sample rates may miss many of the high frequency peaks.

The highest background velocity recorded during the passing of a train on November 14 was 0.0944 in/s at 200 Hz peak frequency. The peak was recorded with the NOMIS system with the highest sample rate.

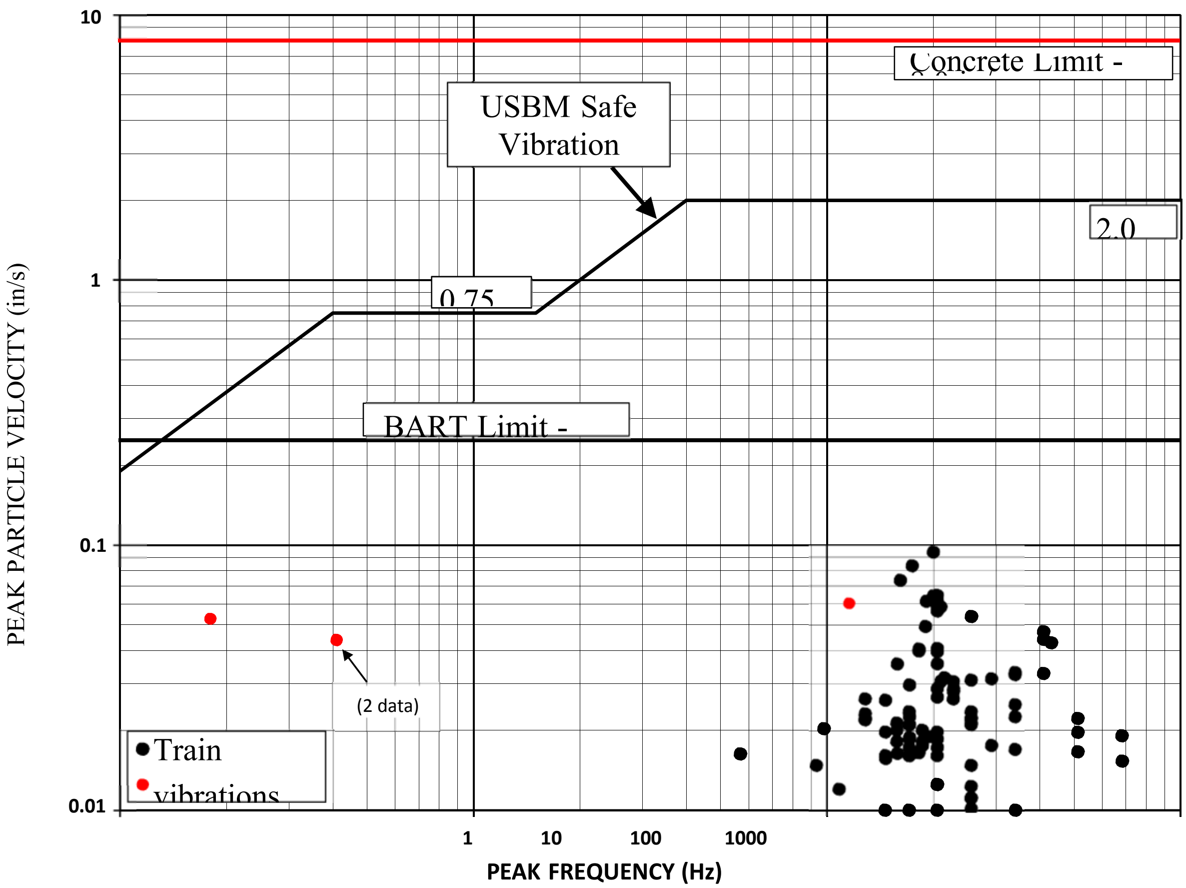
The highest vibration on the wall from the blast was 1.55 times lower than the highest train vibration and more than four times lower than the BART significance threshold of 0.25 inches per second, as shown in Figure 75.

Source: The Chronicle/Kim Komenich

Figure 74. BART Transbay Tube

Table 26. Summary of blast vibrations

Serial No.	Manufacturer	Model	Low-end resolution (in/s)	Upper Range (in/s)	Sample rate (S/s)	Record length (s)	Peak Particle Velocity (in/s)	Peak Frequency (Hz)	FFT Frequency (Hz)	Acceleration (g's)	Displacement (in)
2407	White	Miniseis II	0.0003	0.163	2048	6	0.044	4.1	4.13	0.0398	0.0018
5159	White	Miniseis II	0.0025	0.65	2048	6	0.044	4.1	4.13	0.0638	0.0016
7211	White	Miniseis III	0.0025	1.25	4096	12	0.053	1.8	1.25	0.0629	0.0018
20049	NOMIS	Supergraph II	0.0006	10	16384	12	0.061	115.3	3.76	0.1137	0.0036



Note:
Wall velocity versus frequency for train vibrations compared with blast vibrations plotted on the US Bureau of Mine safe vibration criteria; the BART vibration limit and safe recommended limit used in the blasting industry for concrete are also shown.
Source: Siskind et al. 1980

Figure 75. Wall Velocity Versus Frequency for Train Vibrations Compared with Blast Vibrations

Chapter 7. Summary and Lessons Learned

7.1. Summary

The Demonstration Project was a success based on results described in this report. It was completed safely and resulted in lower levels of impact than anticipated. The Department believes that the use of controlled blasting should be considered as a viable option for marine foundation removal for the SFOBB Project. A summary of the Pier E3 Demonstration Project conclusions follows:

- Safety was top priority! No injuries occurred to project personnel or the public
- Pier E3 was removed to the desired depth, the majority of debris successfully fell into caisson cells; cleanup activities were completed by December 11, 2015
- The Blast Attenuation System effectiveness was at or around modeled levels
- Measured cSEL levels were lower than modeled; measured peak pressure levels were slightly above what was modeled
- No birds or marine mammals were impacted
- Cage Fish Study indicated low fish mortality, observed mortality likely due to handling stress
- CDFW Required Trawls: no state or federally listed fish species were collected; low mortality observed, mortality likely due to handling stress
- Water quality impacts were less than predicted
- Bird predation on fish occurred within the area where large amounts of implosion debris was observed immediately following blast
- Traffic and BART stops were successful

7.2. Lessons Learned

During the course of the Demonstration Project, the Department evaluated areas that could be improved, expanded upon or be done more efficiently. While always looking for ways to improve the methodology of construction to be safer, more cost effective and more environmentally protective, the Department strives to incorporate lessons learned into future projects. The following summarizes the main areas where the Department sees opportunities for improvement:

- Develop a more comprehensive hydroacoustics monitoring plan including:
    - Increased instrument redundancy; and
    - Enhanced equipment reliability and deployment procedures;
- Improve Bird Predation Monitoring Methods to better quantify and distinguish actual bird strikes on fish versus strikes on other organic and inorganic floating material;
- Attempt to develop a system to effectively collect and contain debris generated by the blast;
- Research the efficacy of marine mammal deterrent devices to ensure members of these species will not enter marine mammal exclusion zones; and
- Refine the Caged Fish Study and improve acclimation procedures and staging for the caged fish study subjects.

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Appendix A. Response to Comments matrix

Comment No.	Agency	Date	Agency Question/Comment	Caltrans' Response to Comments	Response Included in Final E3 Report? (Y/N)
1	BCDC	2/11/2016	**Special Condition II.G.5.a** requires that necropsies be conducted on perished fish from the trawls. According to page 131, necropsies were conducted on "37 injured fish." Were necropsies conducted on dead fish? The report also says that a "small number" had injuries that could have been attributed to the implosion. How many?	For the purposes of this effort, moribund fish were considered to be perished. A moribund fish is not technically dead, but is unable to swim or maintain an upright position in the water column, and thus would almost certainly result in a death if more time was allowed to pass. Moribund and dead fish were lumped together into the same data class—the distinction between the two was not recorded. A total of 71 out of 1,158 fish captured in the trawls were moribund or dead. Necropsies were performed on 37 of those 71. In addition, 4 fish were collected on the surface and necropsied. Of these 41 total fish necropsied, only 2 had the kind of severe hemorrhaging that would most likely to be blast-related and these were 2 of the surface water fish caught closer to the pier. The rest of the fish were noted as having either no visible injuries (22) or only light hemorrhaging (17). This light hemorrhaging/damage was so minor that it could be attributed to the blast, caused by the trawling nets, or caused by handling. Based on how far the majority of these fish were collected from the pier, their injuries were most likely the result of the trawling net and handling, not the blast.	Y See Section 6.4.4.
2	BCDC	2/11/2016	**Special Condition II.G.5.c** requires hydroacoustic monitoring. Please explain how the sound pressure differed between the deeper and shallower areas. What does this tell us about possible future implosions of piers in shallower water?	For Pier E3, the water depths surrounding the Pier and out to the monitoring locations were from about 40ft to 50ft. Monitoring was performed at a depth of 20ft. The results did not indicate any dependence on water depth. For shallower water, the peak pressure should not change as it only depends on the direct path of sound traveling from the pier to the receiver location. For SEL, the levels would be lower in shallower water for same distances monitored for Pier E3. This occurs as the received sound depends on both the direct and surface reflected sound. In shallower water, there is more interference between the direct and reflected sound causing lower SEL values.	N
3	BCDC	2/11/2016	**Special Condition II.G.5.e** requires water quality monitoring. In particular: Caltrans is required to "map the plume predicted by the three-dimensional hydrodynamic and sediment transport modeling, bathymetry of the Pier 3 area and anticipated tidal conditions." - As I am new on this project, it is unclear to me whether Caltrans was supposed to provide a predicted map of the plume or to map the plume, which was previously predicted. How does Caltrans understand this condition? Monitoring should have included sensors for pH, turbidity, DO, temperature, depth and an Acoustic Doppler Current Profiler with a GPS and data acquisition system. However, the report did not provide results for turbidity, DO, temperature and depth. These should be included in the report. Also, was an Acoustic Doppler Current Profiler used? Grab samples should have measured suspended sediment concentration and total and dissolved metals. Please provide the results of these measurements.	-Plume map/mapping. The Water Quality team mapped the plume and through that effort has also created a map of the plume track as it moved south after the implosion. A plan view of the plume path will be provided in the Water Quality Monitoring Results (WQMR) report to be submitted to the agencies under separate cover. Additionally, an appendix to the WQMR report will provide a horizontal profile of selected plume transects. -pH, turbidity, DO, temperature, and depth were continuously measured and latitude and longitude of these measurements were recorded using GPS. The acoustic Doppler current profiler was not used because other methods were implemented to measure current speed and to track the plume. A summary of post-implosion water quality results for pH and turbidity are included in Table 22 in Section 6.3.3 of the final report. The WQMR report will contain the full range of turbidity, DO, temperature and depth readings in the body of the text with field data sheets contained in the appendices. -Water grab samples (five "casts"), using a 5-L Niskin bottle, were collected at three depths (top, middle, and bottom) and analyzed for total and dissolved metals. Each cast included a vertical water column profile using the conductivity-temperature-depth profiler. Grab samples were tested for dissolved and total metals and suspended sediment concentration. The WQMR Report discusses the water quality results in more detail and will be submitted under separate cover.	N
4	BCDC	2/11/2016	**Special Condition II.G.5.f** Please provide the volume of debris that fell into the caisson after the implosion, prior to rubble management. What volume of rubble fell outside the footprint of the pier and over what area? The report cites that 2,200 cy was mounded on top of the caisson or next to the caisson.	Approximately 9,550 cubic yards of material fell into the caissons immediately after the implosion and before rubble management began. Caltrans transmitted the PIER E3 DEMONSTRATION PROJECT CLEANUP & HYDROGRAPHIC SURVEY REPORT on December 29, 2015 to comply with Special Condition II.G.5.f. The report includes further detail on the final bathymetry and debris management resulting from the project. That report includes the estimated volume of concrete that was managed during mechanical dismantling, after the Pier E3 implosion and post rubble management. Approximately 2,200 cubic yards is the estimated volume that required clean-up from outside of the caisson. This debris was estimated to cover an area approximately 7,000 square feet around the pier, a majority of it being on the south side of the pier.	N
5	BCDC	2/11/2016	**Special Condition II.G.5.g** - Where are the locations of the five monitoring stations that were used to monitor for water quality impacts to eelgrass? Please show them on a map. - Please provide the final elevation of the rubble within the pier. - What are possible improvements to minimization measures and monitoring, and what are the lessons learned? - Please provide an evaluation of whether implosions are appropriate for the demolition of the other piers.	Autonomous monitoring buoys were placed along the eastern edge of Treasure Island and on the north and south sides of the eastern edge of Yerba Buena Island. These locations corresponded to the locations of eelgrass beds closest to Pier E3. A map has been included in the final report as Figure 69 in Section 6.3 of the final report. Final elevation of rubble within the caisson was no higher than -50 feet NGVD. A brief summary of Lessons Learned is included in Chapter 7, Section 7.2 of the final report. As Caltrans evaluates the means and methods for future pier implosions, a more comprehensive Lessons Learned memo will be prepared and will be submitted separately. The intent of this report is to provide an evaluation of the use of controlled blasting as a viable dismantling method for marine foundation removal. Based on the data provided by this report, Caltrans believes that use of controlled blasting is a viable option that provides less potential environmental impacts as compared to the already authorized mechanical dismantling methods.	Y See Section 6.3. for eelgrass buoy map See Section 7.2. for Lessons Learned

Comment No.	Agency	Date	Agency Question/Comment	Caltrans' Response to Comments	Response Included in Final E3 Report? (Y/N)
6	BCDC	2/11/2016	**Other comments:** It would be helpful to see the measured isopleths for the fish and marine mammals on a map.	These isopleth maps have been added to Section 6.2.5.3 of the report.	Y See Section 6.2.5.3.
7	BCDC	2/25/2016	What is the area (square feet) of the rubble that fell outside the caisson?	Caltrans has estimated that an area of approximately 7,000 square feet, the majority of which occurred on the south side of the pier, had rubble that fell outside of the pier's footprint. The debris that fell out of the pier's footprint to the north east and west sides approximately within 15 feet from the pier. To the south side of the pier, where the greatest extent of debris fell, the debris fell approximately within 60 feet away from the pier.	N
8	CDFW	2/17/2016	The California Department of Fish and Wildlife (Department) has completed its preliminary review of the draft report for the Pier E3 Demonstration Project (Project). Our preliminary analysis of the Project results concluded that of the possible methods for dismantling Pier E3, controlled implosion was likely the least environmentally impactful method for dismantling the underwater pier. Given this determination, the Department does not object to Caltrans moving forward with the implosion methodology for demolishing the remaining piers.	No Response Required	N
9	NOAA	2/23/2016	In general there are quite a few grammatical errors to fix throughout the document	A thorough grammar review was performed.	Y Universal change
10	NOAA	2/23/2016	The project is the SFOBB East Span not *spans* Seismic Safety Project. I recommend a universal search and replace	Agreed, a find and replace for *spans* when referring to the SFOBB project title has been performed.	Y Universal change as applicable
11	NOAA	2/23/2016	Section 3.2.3 pg. 17. Critical habitat for green sturgeon has been finalized as of 10/9/2009. The information for green sturgeon needs to be updated in his section.	Information regarding critical habitat for green sturgeon has be updated. See change in Section 3.2.3.1.	Y See Section 3.2.3.1.
12	NOAA	2/23/2016	Section 4.1.1 page 20. There is no "take" for EFH, EFH consultations are based on the analyses of effects on EFH, which supports those species managed under the MSA. We consult on adverse effects to EFH, not take of individuals under the MSA. "Take" is a term used for the ESA.	Revised language to discuss potential adverse effects to EFH. See change in Section 4.1.1.	Y See Section 4.1.1.
13	NOAA	2/23/2016	Section 4.1.1 page 20, first bullet. Under the ESA, the consultation was based on effects to the listed species that could be present or have CH in the area. There would be no consultation if [Caltrans] truly made a no effect determination. Rather, for all species other than green sturgeon, the determination was a "may affect, not likely to adversely affect, nor adversely modify CH for the species. For green sturgeon, the effect determination was a potential to adversely affect, thus [Caltrans] was exempted incidental take for that species, as well as for the temporary impacts to their CH. Also, [Caltrans] or Federal lead agency does not make the jeopardy determination, that is the responsibility of the Services, either NOAA or USFWS.	Revised language per comment, to match affect determinations from the 2015 BO. See changes in Section 4.1.1.	Y See Section 4.1.1.
14	NOAA	2/23/2016	Section 4.1.1 Page 20. Regarding the last sentence and the BAS system. The BAS system was not really implemented to avoid take, we knew take would occur, but it was rather there to minimize the extent of area affected, thereby reducing the amount of take that was expected to occur as well as reduce the area of EFH adversely affected. I guess its more of a preferred word choice :)	Language revised to describe BAS as a minimization measure, as opposed to an avoidance measure. See change in Section 4.1.1.	Y See Section 4.1.1.
15	NOAA	2/23/2016	Section 4.1.1 second bullet, page 21. See previous comments, the effects determination for green sturgeon is incorrect. If green sturgeon would have been anywhere within the vicinity of the ensonified area around E3, they were considered to be adversely affected, thus the entire reason for the biological opinion and not an LOC.	Revised language per comment, to match effects determination from the 2015 BO. See change in Section 4.1.1.	Y See Section 4.1.1.
16	NOAA	2/23/2016	Section 4.1.1 page 21. regarding the FHWG: Just for clarification, the current thresholds for pile driving were established from impulsive sound sources at the time since there was very little info about pile driving. Seismic sound and explosives were used to develop the criteria, that is why we felt it was suitable to use for the E3 project.	Language suggesting that criteria for injury to fish were based on pile driving has been removed. See change in Section 4.1.1.	Y See Section 4.1.1.
17	NOAA	2/23/2016	Section 4.1.1 last paragraph, page 21. The thresholds are also used to determine the *onset* of injury that can be any type of barotrauma, physical injury that is not solely auditory damage.	Revised text per comment to clarify criteria are based on onset of injury, not solely auditory damage. See change in Section 4.1.1.	Y See Section 4.1.1.
18	NOAA	2/23/2016	Section 4.1.1 page 22, second bullet: temporary impacts to CH and EFH were also expected from the water quality issues associated with the blast, but also clean-up, etc.	Text revised to include impacts to CH and EFH from pier implosion and removal of debris. See change in Section 4.1.1.	Y See Section 4.1.1.

Comment No.	Agency	Date	Agency Question/Comment	Caltrans' Response to Comments	Response Included in Final E3 Report? (Y/N)
19	NOAA	2/29/2016	Section 5.2.1, page 31. The interim thresholds were established based on the available data from impulsive sound sources on fish. This was primarily from blasts and seismic surveys, there was very little known at the time about pile driving.	Removed language stating the criteria was based on noise from pile driving . See change in Section 5.2.1.	Y See Section 5.2.1.
20	NOAA	2/29/2016	Section 5.2.1., page 31. When making reference to the thresholds, cumulative SEL (cSEL) should always be noted since there is also single-pulse SEL also. This is an important distinction.	Revised to cSEL throughout document.	Y Universal change
21	NOAA	2/29/2016	Section 5.2.1. page 31. The 150 dB RMS is not part of the interim criteria for thresholds, but it is the most current level we use to assess potential non or sub-injury to fish, therefore it is considered something that we "regulate" for the purposes of our consultations and identifying a continuum of effects within the sound field.	Sentence stating 150 dB RMS is not "regulated" has been removed. See change in Section 5.2.1.	Y See Section 5.2.1.
22	NOAA	2/29/2016	Section 5.2.2.1. page 33. There is a little mix-up here. When we originally developed the thresholds for pile driving, the only metric that was typically applied was a peak pressure. It was determined though that we needed a total dose response, thus, the cSEL metric was added, giving us the "dual" metric thresholds. So Peak pressure was always there, then cSEL was added.	Text revised to clarify that initial criteria was based on peak pressure and cSEL was added later to capture total dose response. See change in Section 5.2.2.1.	Y See Section 5.2.2.1.
23	NOAA	2/29/2016	Section 5.2.2.2 . Page 34. Again, please make the distinction between a single pulse SEL versus a cSEL.	Revised to cSEL throughout document.	Y Universal change
24	NOAA	2/29/2016	Section 5.2.3. page 36, last paragraph, first sentence please add the word "level" after sound exposure...	Edit made. See change in Section 5.2.3.	Y See Section 5.2.3.
25	NOAA	2/29/2016	Section 5.3. page 68. I am not going to go into any great detail about the caged fish study at this time. But would be willing to discuss aspects of it if another is being proposed.	Caltrans is planning to conduct a Caged Fish Study for Piers E4 and E5. Caltrans welcomes a discussion and hopes resources agencies will partner with Caltrans on the endeavor to take advantage of the opportunity to use state of the art technology for the advancement of science.	N
26	NOAA	2/29/2016	Section 5.3.1.4. page 71. It does not appear that any of the trawl passes occurred in any of the actual blast injury zones. Therefore, no fish would likely show signs of barotrauma unless due to the time it took after to begin the trawl they had moved into the trawl area. It seems that the trawl data is inconclusive for assessing any effects on fish from the blast.	The trawling was conducted between the predicted 187 dB and 183 dB cSEL zones. Measured cSEL distances to the 187 and 183 dB zones were much smaller than the predicted zones, so these fish were likely not exposed to harmful sound levels. The south trawl may have encountered fish that could have been within those injury zones during the blast and that drifted south with the tides following the blast, however there is no way to confirm this. Trawling was not a very effective method for assessing injury from the Pier E3 implosion because it could not be conducted safely close enough to the pier to capture fish that may have been harmed. Language has been added clarifying that trawling locations did not correspond with measured distances to threshold criteria. See change in Section 5.3.1.4.	Y See Section 5.3.1.4.
27	NOAA	2/29/2016	Section 5.3.1.6. page 75. What were the other external physical parameters that were assessed for fish? Was it only whether or not they could remain upright?	Fish behavior was observed in each cage to assess swimming performance, orientation and reaction to stimuli. This assessment classified fish as normal, impaired or dead. All impaired and dead fish were necropsied along with a subsample of normal fish. The necropsy looked at external and internal injury and each fish was scored based on those attributes on the data sheet.	N
28	NOAA	2/29/2016	Section 5.3.1.6. page 75. Why were fish that did not immediately show signs of balance issues released so soon? Why were they not held for observation?	Release of these fish occurred from between one and three hours post blast exposure. The fish were not held longer because the assessment protocols were based on immediate injury and included an assessment of behavior plus a necropsy.	N
29	NOAA	2/29/2016	Section 5.3.1.6. page 75. Did the fish biologists who performed the necropsies have specific experience with assessment of barotrauma?	Dr. Gary Marty, DVM, Ph.D. is a fish pathologist with an established record conducting necropsies on of fish exposed to sound. He was the only biologist that conducted the necropsies for this project and examined and scored every fish. This was intentionally done to minimize any observer bias. Other biologists helped to weigh, measure and prep the fish for necropsy, but Dr. Marty was the only person conducting and scoring the external and internal assessments.	N
30	NOAA	2/29/2016	Section 6.2.5.1. page 116. Although there is uncertainty as to why there were these two high peak levels, fish exposed to a single pulse this high could have been injured or killed.	Agreed. No edit made to report text. No death or injury in the caged fishes that could have been attributed to over/underpressure exposure was observed. Two fish had signs of internal hemorrhaging (barotrauma), one fish at 350 feet and one 3,315 feet from the Pier. Because of their distance from the Pier, both of these injuries were likely related to handling and not barotrauma.	N
31	NOAA	2/29/2016	Section 6.4. page 125. See previous comments on this. I have several concerns about this study that should be discussed if another is going to be proposed.	Caltrans is planning to conduct a Caged Fish Study for Piers E4 and E5. Caltrans welcomes a discussion and hopes resources agencies will partner with Caltrans on the endeavor to take advantage of the opportunity to use state of the art technology for the advancement of science.	N
32	NOAA	2/29/2016	Section 6.4.1.page 125. What were the sound exposure levels for each cage, and how might this relate to injury? The graph should include the sound levels that correspond with the distances of the cages.	Sound exposure levels at each cage distance are included in Table 23 in Section 6.4.1 of the final report.	Y See Section 6.4.1.
33	NOAA	2/29/2016	Section 6.4.1. page 125. There needs to be significantly more information on the types of injuries. What has been omitted from any of this discussion is the state of the swim bladder and state of buoyancy of the fish during the implosion. What was the external condition of the fish prior to exposure to the blast? Were they all visually inspected before being placed in the cages?	The full details of the necropsy results are in Dr. Gary Marty's Necropsy Report, appended to the Caged Fish Immediate Mortality and Injury and Trawling Report, which can be provided separately. The swim bladder was assessed on every fish necropsied. All swim bladders were intact and fully inflated (= score of 0). Two fish that showed signs of hemorrhaging, one on the ventral surface of the swim bladder and one on the surface of the intestinal mesenteries - were deployed at 350 and 3,315 feet respectively. The study design used a deployed cage control (fish that were deployed and not exposed to the blast) and non-deployed net pen controls (fish from the net pen) to account for handling effects. All fish that were moved into the cages were inspected at the dock prior to transferring the cages to the buoy line. They were inspected again in the vessel prior to moving the cage overboard.	Y See Section 6.4.1.

Comment No.	Agency	Date	Agency Question/Comment	Caltrans' Response to Comments	Response Included in Final E3 Report? (Y/N)
34	RWQCB	2/19/2016	SWPPP Amendment #4 described that booms will be deployed prior to the implosion and skimmers would be used to collect and remove floating materials after the implosion. It did not appear that booms or skimmers were deployed before or after the implosion. Were booms and skimmers used to contain and capture floating implosion debris, and if not, why?	Booms were not deployed prior to implosion. A decision was made not to deploy booms around the work area during implosion because of safety and environmental monitoring access concerns. The changed plan was conveyed as part of SWPPP Amendment 8 which also stated that a skimmer would be used to collect wood that may break off of the implosion platform system. After the implosion, skiff boats were used to collect floating debris – mostly large debris, but some small debris was collected as well. Additionally, as discussed during the March 4, 2016 meeting with the Water Board (where Pier E3 implosion water quality and future Pier E4-E18 BMPs and water pollution control measures were discussed), if significant changes are made to the pollution prevention plan for future pier dismantling activities, both verbal and written (i.e., email) correspondence will clearly highlight these changes.	N
35	RWQCB	2/19/2016	Before the implosion, a foamy, grayish, substance was accumulating at the surface around the pier. After the implosion, this substance disbursed and was floating widely around the implosion site. Did [Caltrans] investigate what this foamy substance was composed of? It did not appear a boom or skimmer was deployed to contain this substance, is this the case?	Foam was observed around the pier. The most likely source of this foam was aerated San Francisco Bay waters and the cause of this aeration was pressurized air being released from the blast attenuation system (BAS) surrounding Pier E3. Water Quality sampling personal located north of and near Pier E3 reported that the foam had a consistency similar to sea foam (i.e., foam generated by the mechanical aeration of wind or wave action). Additionally, the BAS was tested two times prior to the implosion. During both of those testing events, a similar sea foam was observed. Because the foam was observed before the implosion (immediately after activating the BAS) and during previous BAS testing events, it was not considered a nuisance and therefore no attempt to remove it was made.	N
36	RWQCB	2/19/2016	The SWPPP amendment described a decanting barge and operation that would occur during the clamshell operation. During the clamshell removal of debris from the bay floor after the implosion, was any material off-hauled, or was all demo material placed in the caisson? The report does not mention any off-hauling. What was the reason to describe the decanting and mechanical separation of demo material in the SWPPP amendment?	a. None of the Pier E3 debris field that was found surrounding the former Pier E3 boundary was brought to the surface. All this debris was moved from outside the Pier E3 boundary and placed into the caissons. However, the obstructions that were identified in mid-2015 that hindered the initial placement of the BAS were removed after the implosion. This is in keeping with Caltrans's commitment to the Water Board that after the implosion was complete, any debris that was moved to allow placement of the BAS would later be removed. Two steel pipes were removed. b. The SWPPP amendment described the decanting and mechanical separation of the material as a precaution in the event more material needed management than there was space within the caisson void. While it was the intention that all of the material would fall into the caisson, there was a chance that the voids may have been obstructed with material that got tangled up with rebar after the implosion or for whatever reason was a larger quantity than anticipated. Off-hauling the material may have been necessary in the event the material couldn't be deposited to at least 1.5 feet below mudline within the caisson. This did not end up occurring and so the decanting barge was not used.	N
37	RWQCB	2/19/2016	Will there be a stand-alone water quality and sediment sampling report submitted that includes the reporting information described in the Sampling and Analysis Plan?	Yes. A stand alone water quality report summarizing the results will be submitted separately from this post blast report.	N
38	USACE	3/14/2016	Did you...get the sediment samples that the report said would come in around late February and the metals samples which were going to be "available at a later date"?	A stand alone water quality report summarizing the results will be submitted separately from this post blast report.	N
39	USACE	3/14/2016	What was done with the filters from the pre and post-implosion filtered water?	The filters were sent for disposal to a non-hazardous solid waste landfill. Text added to Section 6.3.2.	Y See Section 6.3.2.

Contributing Agencies:

BCDC - San Francisco Bay Conservation and Development Commission
CDFW - California Department of Fish and Wildlife
NOAA - National Oceanic & Atmospheric Administration - National Marine Fisheries Service (Fisheries)
RWQCB - San Francisco Bay Regional Water Quality Control Board
USACE - United States Army Corps of Engineers